STILL LIVING WITH MORTALITY: THE LONGEVITY RISK TRANSFER MARKET AFTER ONE DECADE

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ABSTRACT

This paper updates *Living with Mortality* published in 2006. It describes how the longevity risk transfer market has developed over the intervening period, and, in particular, how insurance-based solutions – buy-outs, buy-ins and longevity insurance – have triumphed over capital markets solutions that were expected to dominate at the time. Some capital markets solutions – longevity-spread bonds, longevity swaps, *q*-forwards, and tail-risk protection – have come to market, but the volume of business has been disappointingly low. The reason for this is that when market participants compare the index-based solutions of the capital markets with the customized solutions of insurance companies in terms of basis risk, credit risk, regulatory capital, collateral, and liquidity, the former perform on balance less favourably despite a lower potential cost. We discuss the importance of stochastic mortality models for forecasting future longevity and examine some applications of these models, e.g., determining the longevity risk premium and estimating regulatory capital relief. The longevity risk transfer market is now beginning to recognize that there is insufficient capacity in the insurance and reinsurance industries to deal fully with demand and new solutions for attracting capital markets investors are now being examined – such as longevity-linked securities and reinsurance sidecars.

KEYWORDS

Longevity Risk; Buy-Outs; Buy-Ins; Longevity Insurance; Longevity Bonds; Longevity Swaps; *q*-Forwards; Tail-Risk Protection; Basis Risk; Credit Risk; Regulatory Capital; Collateral; Liquidity; Stochastic Mortality Models; Longevity Risk Premium; Longevity-Linked Securities; Reinsurance Sidecars

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1. INTRODUCTION

1.1 *Background*

1.1.1 A little over a decade ago, the longevity risk transfer market started. This is now a global market, but it began in the UK in 2006. To coincide with the setup of this market, the British Actuarial Journal published *Living with Mortality* (Blake et al., 2006a). That paper examined the problem of longevity risk – the risk surrounding uncertain aggregate mortality – and discussed the ways in which life insurers, annuity providers and pension plans could manage their exposure to this risk. In particular, it focused on how they could use mortality-linked securities and over-the-counter contracts – some existing and others still hypothetical – to manage their longevity risk exposures. It provided a detailed analysis of two such securities –

the Swiss Re mortality bond issued in December 2003 and the European Investment Bank (EIB)/BNP Paribas longevity bond announced in November 2004. It then looked at the universe of hypothetical mortality-linked securities – other forms of longevity bonds, swaps, futures and options – and investigated their potential uses. It also addressed implementation issues, and drew lessons from the experience with other derivative contracts. Particular attention was paid to the issues involved with the construction and use of mortality indices, the management of the associated credit risks, and possible barriers to the development of markets for these securities. The paper concluded that these implementation difficulties were essentially teething problems that would be resolved over time, and so leave the way open to the development of a flourishing market in a brand new class of capital market securities.[1]

1.1.2 In the event, the EIB/BNP longevity bond did not attract sufficient demand to get launched. The Swiss Re mortality bond, known as Vita,[2] was followed by broadly similar bonds from both Swiss Re and other issuers, but the overall size of the issuance was fairly small. Swiss Re also pioneered the successful issuance of a longevity-spread bond, known as Kortis,[3] but again the size of the issue was small. Investment banks, such as JP Morgan and Société Générale, introduced some innovative derivatives contracts – q-forwards and tail risk protection – but, so far, only a few of these contracts have been sold. Overall, then, the demand for the capital market solutions that have been proposed for hedging longevity risk has been disappointingly low.

1.1.3 By contrast, the solutions offered by the insurance industry have been much more successful. The key examples are the buy-out, the buy-in and longevity insurance. In other words, pension plan advisers and trustees preferred dealing with risk by means of insurance contracts which fully removed the risk concerned and were not yet comfortable with capital market hedges that left some residual basis risk.

1.2 *Focus of this Paper*

The present paper provides a review of the developments in longevity risk management over the last decade or so. In particular, we focus on the ways in which pension plans and life insurers have managed their exposure to longevity risk, on why capital market securities failed to take off in the way that was anticipated ten years ago, and what solutions for managing longevity risk might become available in the future.

1.3 *Layout of this Paper*

The paper is organized as follows. Section 2 quantifies the potential size of the longevity risk market globally. Section 3 discusses the different stakeholders in the market for longevity risk transfers. Sections 4 and 5, respectively, examine the structure of the successful insurance-based and capital market solutions that have been brought to market since 2006. The distinction between index and customized hedges and the issue of basis risk are investigated in Section 6, while Section 7 looks at credit risk, regulatory capital and collateral, and Section 8 discusses liquidity. Stochastic mortality models are crucial to the design and pricing of longevity risk transfer solutions and these are reviewed in Section 9, while some applications that use these models are considered in Section 10. Section 11 reviews the developments in the longevity de-

[1] As originally suggested in Blake and Burrows (2001), Dowd (2003), and Blake *et al.* (2006b).

[2] http://www.artemis.bm/deal_directory/vita-capital-ltd/

[3] http://www.artemis.bm/deal_directory/kortis-capital-ltd/

risking market since 2006. Section 12 looks at potential future risk transfer solutions that involve the capital markets and Section 13 concludes.

2. Quantifying the Potential Size of the Longevity Risk Market

2.1 Michaelson and Mulholland (2015) recently estimated the potential size of the global longevity risk market for pension liabilities at between \$60trn and \$80trn, comprising:

(i) The accumulated assets of private pension systems in the Organisation for Economic Co-Operation and Development (OECD) were \$32.1trn,[4] arising from: pension funds (67.9%), banks and investment companies (18.5%), insurance companies (12.8%), and employers' book reserves (0.8%) at year-end 2012 (OECD (2013)).

(ii) The US social security system had unfunded obligations for past and current participants of \$24.3trn, as of the end of 2013 (Social Security Administration (2013)).

(iii) The aggregate liability of US State Retirement Systems was an additional \$3trn, as of the end of 2012 (Morningstar (2013)), which does not capture the liabilities of countless US local and municipal pension systems.

(iv) There are public social security systems in 170 countries (excluding the US) that provide old-age benefits of some sort for which reliable size estimates are not readily available but which are certainly substantial.[5]

2.2 Michaelson and Mulholland (2015) then estimated the size of the longevity risk underlying these liabilities. Each additional year of unanticipated life expectancy at age 65– roughly equivalent to a 0.8% increase in mortality improvements or a 13% reduction in mortality rates[6]– can increase pension liabilities by 4%–5% (Swiss Re Europe (2012)). Risk Management Solutions (RMS) estimated the standard deviation of a sustained shock to annual mortality improvements (lasting 10 years or more) relative to expectations at around 0.80%. Michaelson and Mulholland use this estimate to calculate the effect of a longevity tail event (i.e., a 2.5 standard deviation event) which corresponds to a 2% change in trend (0.80% × 2.5 = 2%) and, in turn, implies that longevity-related liabilities could grow by as much as 8%–10% as a result of unforeseen mortality improvements. Given aggregate global pension liabilities of \$60–80trn, these could in the extreme increase by \$5–8trn.

2.3 Pigott and Walker (2016) reconfirm the approximate \$30trn estimate of private sector longevity risk exposure.[7] This is concentrated in the US (\$14.460trn), the UK (\$2.685trn), Australia (\$1.639trn), Canada (\$1.298trn), Holland (\$1.282trn), Japan (\$1.221trn), Switzerland (\$0.788trn), South Africa (\$0.306trn), France (\$0.272trn), South America (\$0.251trn), Germany (\$0.236trn) and Hong Kong (\$0.110trn). Pigott and Walker argue that only the US, UK, Canada and Holland currently have the conditions for a longevity risk transfer market to develop.

2.4 The other markets do not currently have the right conditions for the following reasons:

- Australia: Sponsors of pension plans do not bear longevity risk; individuals often buy term (20-year) annuities at retirement, then rely on the state, although a lifetime annuity market is beginning to emerge

[4] Revised to \$38trn at the end of 2016 (OECD(2017) *Global Pension Statistics*).
[5] Social Security Administration: http://www.ssa.gov/policy/docs/progdesc/ssptw/
[6] Own calculations, based on England & Wales mortality forecasts for males aged 65.
[7] Derived from Aon Hewitt calculations, based on data from the OECD and European Insurance and Occupational Pensions Authority (EIOPA).

- Japan: Corporate sponsors of pension plans and insurers do not bear longevity risk, since individuals buy term annuities at retirement; however, there is a growing market for long-term annuities in Japan purchased from Australia.[8]
- Switzerland: Individuals are incentivized but not required to annuitize; the market is small, but may open up in the future
- Germany: Occupational scheme liabilities are written onto company balance sheets as book reserves, so there is no driver to de-risk, despite longevity risk being as significant a risk as it is in other countries
- France: A very small market, although French insurers and reinsurers are active in other markets
- South Africa and South America: Hampered by lack of or unreliable historical mortality data and poor experience data; in Chile, which has a rapidly growing lifetime annuities market, the government effectively underwrites annuity providers which therefore have no incentive to hedge their longevity risk exposure.[9]

3. Stakeholders in the Longevity Risk Transfer Market

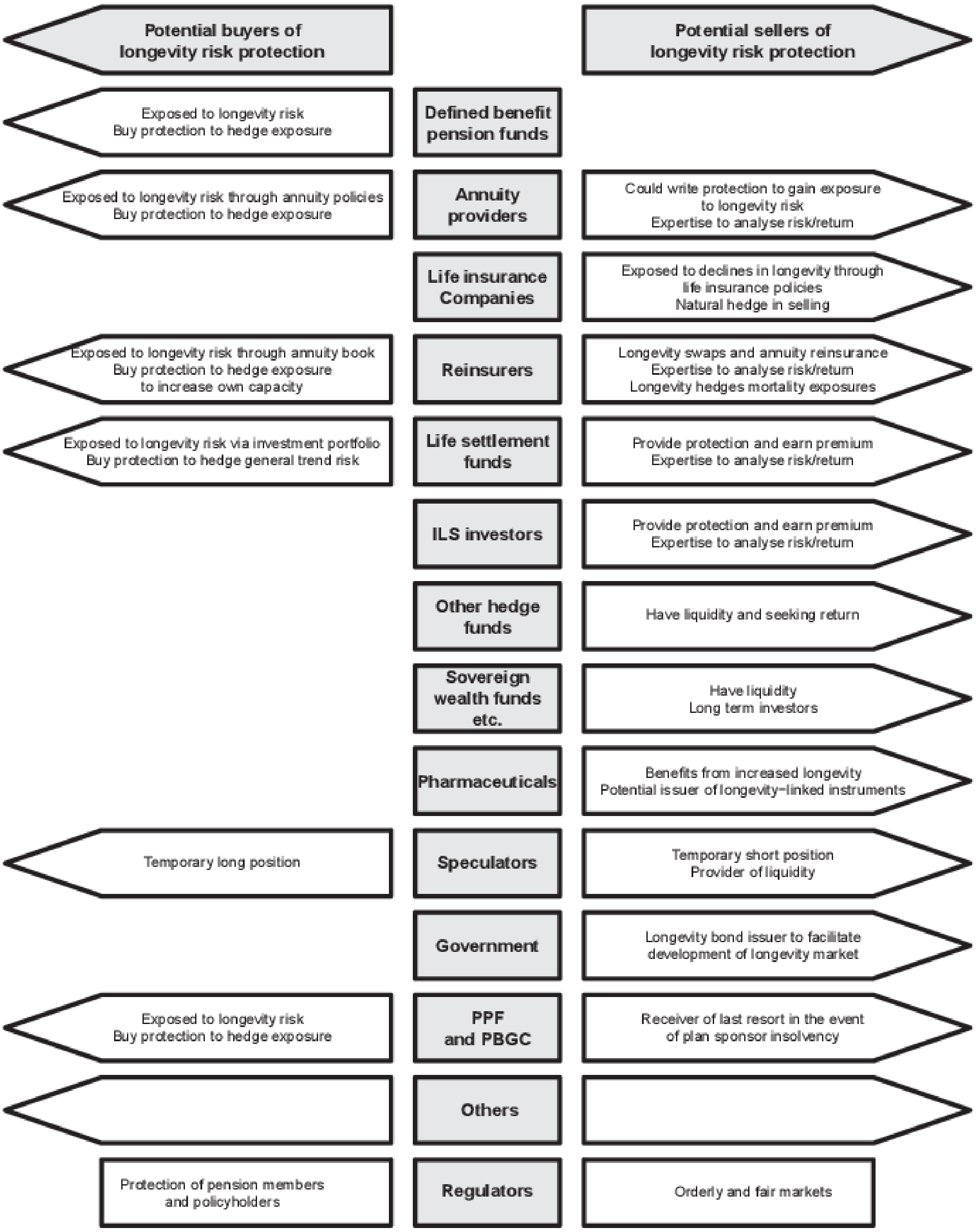
3.1 *Classes of Stakeholders*

Figure 1 shows the participants in the longevity risk transfer market. In this section, we examine the various classes of stakeholders in this market.

[8] Richard Gluyas (2017) Challenger rides tidal wave of Japanese interest in Australian annuities, *The Weekend Australian*, 24 April: 'sales of Australian dollar annuities in Japan are estimated to be worth about $A30 billion a year — about seven times the size of the entire annuities market in Australia'.

[9] See Zelenko (2014)

Figure 1: Participants in the Longevity Risk Transfer Market



(*Source:* Adapted from Loeys et al. (2007, Chart 10)

3.2 *Hedgers*

3.2.1 One natural class of stakeholders are hedgers, those who have a particular exposure to longevity risk and wish to lay off that risk. For example, defined benefit pension funds and annuity providers stand to lose if mortality improves by more than anticipated, whilst life insurance companies stand to gain, and vice versa. These offsetting exposures imply that annuity providers and life assurers, for example, can hedge each other's longevity risks.[10] Alternatively, parties with unwanted exposure to longevity risk might pay other parties to lay off some of their risk. For instance, a life office might hedge its longevity risk using a reinsurer or by selling it to capital market institutions.

3.2.2 As another possibility, pharmaceutical companies benefit if people live longer, since they (and the health service) need to spend more on medicines as they get older, especially for those in poor health. Also there is a continuous stream of new medical treatments that prolong life. The pharmaceutical companies could potentially issue longevity-linked debt to finance their research and development programmes which, if sufficiently attractive for pension funds to hold, could be issued at a lower cost than conventional fixed maturity debt. In other words, pharmaceutical companies are 'short' on longevity risk – they benefit if longevity increases – and they could put on a counterbalancing long position by selling a longevity bond.[11] While they have been approached about this possibility, no pharmaceutical company has yet issued such debt. The principal reasons appear to be that the finance directors have not been sufficiently educated in the benefits of such an issue – and in any case are more concerned that the millions of dollars being spent on drug trials will bring a sufficient return to shareholders – and because, in practice, the short-term correlation between company profits and longevity is probably not strong enough to persuade finance directors to issue longevity bonds.

3.3 *Specialist and General Investors*

There are specialist investors in this market, such as life settlement[12] investors, premium finance investors,[13] and insurance-linked securities (ILS) investors.[14] Depending on their existing exposures, these investors could either buy longevity protection or sell it and earn a premium. General investors include short-term investors, such as hedge funds and private equity investors, and long-term investors, such as sovereign wealth funds, endowments, family offices etc. Provided expected returns are acceptible, such investors might be interested in acquiring an exposure to longevity risk, since it has a low correlation with standard financial market risk factors. The combination of a low beta and a potentially positive alpha should therefore make mortality-linked securities attractive investments in diversified portfolios.

3.4 *Speculators and Arbitrageurs*

A market in longevity-linked securities might attract speculators: short-term investors who trade their views on the direction of individual security price movements. The active involvement of speculators is important for creating market liquidity as a by-product of their trading activities, and is in fact essential to the success of traded futures and options markets. However, liquidity also depends on the frequency with which new information about the market materializes and this is currently sufficiently low that there is negligible speculator

[10] In many cases, annuity providers and life assurers are part of the same life office, in which case the annuity and life books provide at least a partial 'natural hedge'.
[11] This possibility was first suggested in Dowd (2003).
[12] A life settlement is the US name for a traded life policy.
[13] Premium finance investors provide funding for those wishing to buy life settlements and similar types of policies.
[14] Insurance-linked securities are financial instruments whose values depend typically on the occurrence of prescribed high severity, low probability insurance loss events. The typical events covered are natural catastrophes, such hurricanes and earthquakes, and the values of the ILSs will depend on the value of the property losses if such events occur. ILSs are commonly known as catastrophe or CAT bonds.

interest in the longevity market at the present time. Arbitrageurs seek to profit from any pricing anomalies in related securities. For arbitrage to be a successful activity, it is essential that there are well-established pricing relationships between the related securities: periodically, prices get out of line which creates profit opportunities which arbitrageurs exploit.[15] However, the longevity market is currently not sufficiently well developed for arbitrage opportunities to exist.

3.5 *Government*

3.5.1 The Government has many potential reasons to be interested in markets for longevity-linked securities. It might wish to promote such markets and assist financial institutions that are exposed to longevity risk (e.g., it might issue longevity bonds that can be used as instruments to hedge longevity risk).[16]

3.5.2 The Government might also be interested in managing its own exposure to longevity risk. The Government is a significant holder of this risk in its own right via pay-as-you-go state pensions, pension to former public sector employees and its obligations to provide health care for the elderly. At a higher level, the Government is affected by numerous other economic factors, some of which partially offset the Government's own exposure to longevity risk (for example, income tax on private pensions in payment continues to be paid as people live longer).

3.6 *Regulators*

3.6.1 Financial regulators have two main stated aims: (i) the enhancement of financial stability through the promotion of efficient, orderly and fair markets, and (ii) ensuring that retail customers get a fair deal.[17] The two financial regulators in the UK responsible for delivering on these aims are the Prudential Regulatory Authority (PRA) and the Financial Conduct Authority (FCA).

3.6.2 The PRA has a duty to ensure that the financial system is protected against systemic risks, and longevity risk is a potential example of such a risk. This, in turn, requires that carriers of such risks, such as life insurance companies, hold sufficient regulatory capital to protect them from insolvency with a high degree of probability. The FCA's duty is to ensure that customers get competitive and fairly priced annuity products, for example, and that becomes more difficult if providers of these products cannot easily or economically hedge the longevity risk contained in them.[18]

3.6.3 Another interested regulator is The Pensions Regulator (TPR) which acts as gatekeeper to the UK's pension lifeboat, the Pension Protection Fund (PPF).[19] The TPR wants to reduce

[15] Classic examples are currencies and commodities, such as gold, which are traded in two different markets at different prices. Arbitrageurs will buy in the cheaper market and immediately sell in the dearer market, making an arbitrage profit if the price difference exceeds any transactions costs. The key difference between arbitrageurs and speculators is that the former seek to make a profit without taking on any risks (or at least minimizing the risks they need to take), whereas the latter seek to make a profit from explicitly assuming risks.

[16] As proposed in Blake et al. (2014).

[17] As specified in the Financial Services and Markets Act 2000.

[18] Hedging allows the issuer of an annuity to reduce its exposure to longevity risk which in turn allows it to offer its products at more competitive prices (i.e., closer to the actuarially fair price), since less regulatory capital needs to be posted.

[19] A statutory fund established by the UK Pensions Act 2004 'to provide compensation to members of eligible defined benefit pension plans, when there is a qualifying insolvency

the probability that large companies (in particular) are bankrupted by their pension funds (Harrison and Blake, 2016). As 'insurer of last resort', the Government is also potentially the residual holder of this risk in the event of default by the PPF. The PPF and Government have a strong incentive to help companies hedge their exposure to longevity risk, which would reduce the likelihood of claims on the PPF.

3.7 *Other Stakeholders*

Other domestic stakeholders include healthcare providers and insurers, providers of equity release (or reverse or lifetime) mortgages, and securities managers and organized exchanges, all of which would benefit from a new source of fee income. Members of both defined benefit (DB) and defined contribution (DC) plans have an interest in the security of their current and future pension entitlements, while individuals with state pensioners are ultimately not immune from increases in the government's budget deficit that arise from increases in life expectancy. Longevity risk is a global phenomenon, so there will be similar stakeholders in other countries where this problem is prevalent.

4. Successful Insurance-based Solutions

4.1 Overview

The traditional solution for dealing with unwanted longevity risk in a DB pension plan or an annuity book is to sell the liability via an insurance or reinsurance contract. This is known as a pension buy-out (or pension termination) or, in an insurance context, a group/bulk annuity transfer. More recently, pension buy-ins and longevity insurance (the insurance term for a longevity swap) have been added to the list of insurance-based solutions for transferring longevity risk. Insurance solutions are generally classified as 'customized indemnification solutions', since the insurer fully indemnifies the hedger against its specific risk exposure. These solutions can also be thought of as 'at-the-money' hedges, since the hedge provider is responsible for any increase in the liability above the current best estimate assumption on a pound-for-pound basis.

4.2 Pension Buy-outs

4.2.1 The most common traditional solution for DB pension plans is a full pension buy-out, implemented by a regulated life assurer. The procedure can be illustrated using the following simple example.

4.2.2 Consider Company ABC with pension plan assets (A) of 85 and pension plan liabilities (L) of 100, valued on an 'ongoing basis'[20] by the plan actuary; this implies a deficit of 15. ABC approaches life assurer XYZ to effect a pension buy-out. On a full 'buy-out basis', the insurer values the pension liabilities at 120, a premium of 20 to the plan actuary's valuation, implying a buy-out deficit of 35. The insurer, subject to due diligence, offers to take on both the plan assets A and plan liabilities L provided the company contributes 35 from its own resources (or from borrowing) to cover the buy-out deficit. Following the acquisition, the insurer implements an asset transition plan which involves exchanging certain assets, e.g., equities for

event in relation to the employer, and where there are insufficient assets in the pension plan to cover the Pension Protection Fund level of compensation'. Another example is the US Pension Benefit Guaranty Corporation (PBGC).

[20] In the UK, this would also be known as the FRS 17 (the UK Pension Accounting Standard) basis.

bonds, and implementing interest rate and inflation swaps to hedge the interest-rate and inflation risk associated with the pension liabilities.[21]

4.2.3 The advantages to the company are that the pension liabilities are completely removed from its balance sheet. In the case where the company does not have the cash resources to pay the full cost of the buy-out, the pension deficit (on a buy-out basis) is replaced by a loan which, unlike pension liabilities, is an obligation that is readily understood by investment analysts and shareholders. The company avoids volatility in its profit and loss account coming from the pension plan,[22] the payment of levies to the PPF, administration fees on the plan and the potential drag on its enterprise value arising from the pension plan. The advantage of a buy-out to the pension trustees and plan members is that pensions are now secured in full (subject to the credit risk of the life assurer).

4.2.4 There is a potential disadvantage in terms of timing. Once a buy-out has taken place, it cannot generally be renegotiated if circumstances change and the buy-out price is lower in the future, say, because an increase in long-term interest rates leads to the discount rate used to value pension liabilities also increasing. There is also a potential risk that the buy-out company itself becomes insolvent in which case the pensioners would have no recourse to the PPF. However, since buy-out companies are established as insurance companies with solvency capital requirements,[23] this risk should, in practice, be very low in countries like the UK.

4.3 Pension Buy-ins

4.3.1 Buy-ins are insurance transactions that involve the bulk purchase of annuities by the pension plan to hedge the risks associated with a subset of the plan's liabilities, typically associated with retired members. The annuities become an asset of the plan and reflect the mortality characteristics of the plan's membership in terms of age and gender – but are not written in the names of specific plan members.

4.3.2 Buy-ins are often part of the journey to a full buy-out. They can be thought of as providing a 'de-risking' of the pension plan in economic terms. They enable the plan to lock-in attractive annuity rates over time, without the risk of a spike in pricing at the very time they decide to proceed directly to a full buy-out. Buy-ins also offer the sponsor the advantage of full immunization of a portion of the pension liabilities for a lower up-front cash payment relative to a full buy-out – although the recent introduction of deferred premium payments for both buy-ins and buy-outs has helped to spread costs for both types of product.[24] Since the annuity contract purchased in a buy-in is an asset of the pension plan, rather than an asset of the plan member, the pension liability remains on the balance sheet of the sponsor. Plan members are

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[21] Traditional UK insurers running annuity books interpret UK regulatory capital requirements as restricting them to invest in government and investment-grade corporate bonds and related derivatives.

[22] This volatility is generated by the way in which accounting standards treat DB pension liabilities in a market-consistent way as the present discounted value of projected future pension payments. The required discount rates are related to the market yield on a class of traded bonds (such as AA-rated corporate bonds) of appropriate term. If market conditions are such that this yield is volatile, then the value of the pension liabilities will be similarly volatile, even though the projected stream of future pension payments might have changed very little.

[23] See Section 7.2 for more details.

[24] See para 11.50.

therefore still exposed to the risk of sponsor insolvency if the plan is in deficit and to the (albeit lower) risk of insurer company insolvency unless the buy-in deal has been fully collateralized.

4.4 Longevity Insurance or Insurance-Based Longevity Swaps

4.4.1 A more recent variation on the traditional pension buy-out is the longevity insurance contract or insurance-based longevity swap. This is effectively an insurance version of the capital-markets-based longevity swap (discussed in the next section), which transfers longevity risk only. A typical structure involves the buyer of the swap paying a pre-agreed fixed set of cash flows to the swap provider and receiving in exchange a floating set of cash flows linked to the realized mortality experience of the swap buyer, the latter being used to pay the pensions for which the swap buyer is liable. No assets are transferred and the pension plan typically retains the investment risks associated with the asset portfolio. Longevity swaps have the advantage that they remove longevity risk without the need for an upfront payment by the sponsor and allow the pension plan trustees to retain control of the asset allocation.

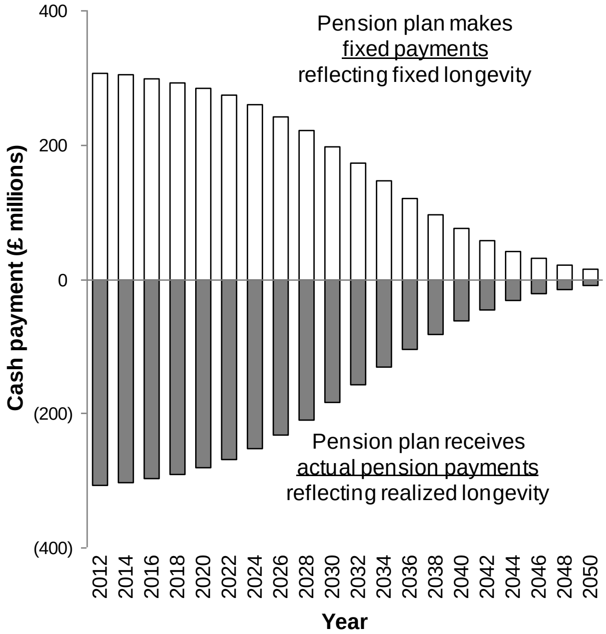
4.4.2 The first publicly announced longevity swap took place in April 2007 between Swiss Re and Friends' Provident, a UK life insurer. It was a pure longevity risk transfer and was not tied to another financial instrument or transaction. The swap was based on Friends' Provident's £1.7bn book of 78,000 of pension annuity contracts written between July 2001 and December 2006. Friends' Provident retains administration of policies. Swiss Re makes payments and assumes longevity risk in exchange for an undisclosed premium.

4.4.3 In any longevity swap, the hedger of longevity risk (e.g., a pension plan) receives from the longevity swap provider the actual payments it must pay to pensioners and, in return, makes a series of fixed payments to the hedge provider.[25] In this way, if pensioners live longer than expected, the higher pension amounts that the pension plan must pay are offset by the higher payments received from the provider of the longevity swap. The swap therefore provides the pension plan with a long-maturity, customized cash flow hedge of its longevity risk.

4.4.4 Figure 2 shows the set of cash flows in a typical longevity swap involving a pension plan wishing to hedge its longevity risk exposure. The plan makes a set of pre-agreed fixed payments and receives the actual pension payments it needs to make and these will be based on its realized longevity experience. Each payment is based on an amount-weighted survival rate (Dowd *et al.*, 2006; and Dawson *et al.* 2010).

Figure 2: A Longevity Swap Involves the Regular Exchange of
Actual Realized Pension Cash Flows and Pre-Agreed Fixed Cash Flows

[25] It is possible that the swap is set up to cover inflation increases (possibly up to a limit), in which case the fixed payments are fixed in real rather than in nominal terms.



Source: Coughlan et al. (2007a).

5. 5. SUCCESSFUL CAPITAL MARKETS SOLUTIONS

5.1 Overview

In this section, we analyse the small number of capital market securities that have been successfully launched since 2006: longevity-spread bonds, *q*-forwards and longevity swaps. The key feature of these is that most are index rather than customized solutions.[26]

5.2 Longevity-Spread Bonds

5.2.1 In December 2010, Swiss Re issued an eight-year catastrophe-type bond linked to longevity spreads. To do this, it used a special purpose vehicle, Kortis Capital, based in the Cayman Islands.[27] The Kortis bond is designed to hedge Swiss Re's own exposure to longevity risk.[28] It had a very small nominal value of just $50m which clearly meant that it was designed to test the water for a new type of capital market instrument.

5.2.2 The bond holders were exposed to the risk of an increase in the spread between the annualized mortality improvement in English & Welsh males aged 75 to 85 and the corresponding improvement in US males aged 55 to 65. The mortality improvements were measured over eight years from 1 January 2009 to 31 December 2016. The bonds matured on

[26] The J.P. Morgan–Canada Life swap discussed in Section 5.3 is one of the few examples of a customized capital markets solution.

[27] http://www.swissre.com/media/news_releases/Swiss_Re_completes_first_longevity_trend_bond_transferring_USD_50_million_of_longevity_trend_risk_to_the_capital_markets.html

[28] It is important to recognize that the Kortis bond is not a true longevity bond in the sense that it hedges the longevity trend in a particular population. Rather it transfers the risk associated with the spread (or difference) between the longevity trends for two different population groups, rather than the trends themselves.

15 January 2017,[29] although there is an option to extend the maturity to 15 July 2019. The principal was at risk if the Longevity Divergence Index Value (LDIV) exceeded the attachment point or trigger level of 3.4% over the risk period. The exhaustion point, at or above which there would be no return of principal, is 3.9%. The principal would be reduced by the principal reduction factor (PRF) if the LDIV lies between 3.4% and 3.9%.

5.2.3 The LDIV is derived as follows. Let $m^y(x,t)$ be the male death rate at age *x* and year *t* in country *y*. This is defined as the ratio of deaths to population size for the relevant age and year. Annualized mortality improvements over *n* years are defined as:

$$Improvement_n^y(x,t) = 1 - \left[\frac{m^y(x,t)}{m^y(x,t-n)}\right]^{\frac{1}{n}}. \qquad (1)$$

The annualized mortality improvement index for each age group is found by averaging the annualized mortality improvements across ages in the group:

$$Index(y) = \frac{1}{1+x_2-x_1}\sum_{x=x_1}^{x=x_2} Improvement_n^y(x,t). \qquad (2)$$

In the case of the Kortis bond, *n* is equal to 8 years. The LDIV is defined as:

$$LDIV = Index(y_2) - Index(y_1) \qquad (3)$$

where y_2 is the England & Wales population aged 75-85 and y_1 is the US population aged 55-65. The PRF is calculated as follows:

$$PRF = \frac{LDIV - Attachment\ point}{Exhaustion\ point - Attachment\ point}, \qquad (4)$$

with a minimum of 0% and a maximum of 100%.

5.2.4 Proceeds from the sale of the bond were deposited in a collateral account at the AAA-rated International Bank for Reconstruction and Development (i.e., the World Bank). If there is a larger-than-expected increase in the spread between the mortality improvements of 75-85 year old English & Welsh males and those of 55-65 year old US males, part of the collateral will be sold to make payment to Swiss Re and, as a consequence, the principal of the bond would be reduced. The exposure that Swiss Re wished to hedge comes from two different sources. For example, Swiss Re is the counterparty in a £750m longevity swap with the Royal County of Berkshire Pension Fund which was executed in 2009, and so is exposed to high-age English & Welsh males living longer than anticipated. It has also reinsured a lot of US life insurance policies and is exposed to middle-aged US males dying sooner than expected. The longevity-spread bond provided a partial hedge for both exposures and helped Swiss Re reduce its regulatory capital.

5.2.5 Standard & Poor's rated the bond BB+ which took into account the possibility that investors would not receive the full return of their principal. This rating was determined using two models developed by RMS which was appointed as the calculation agent for the bonds.[30]

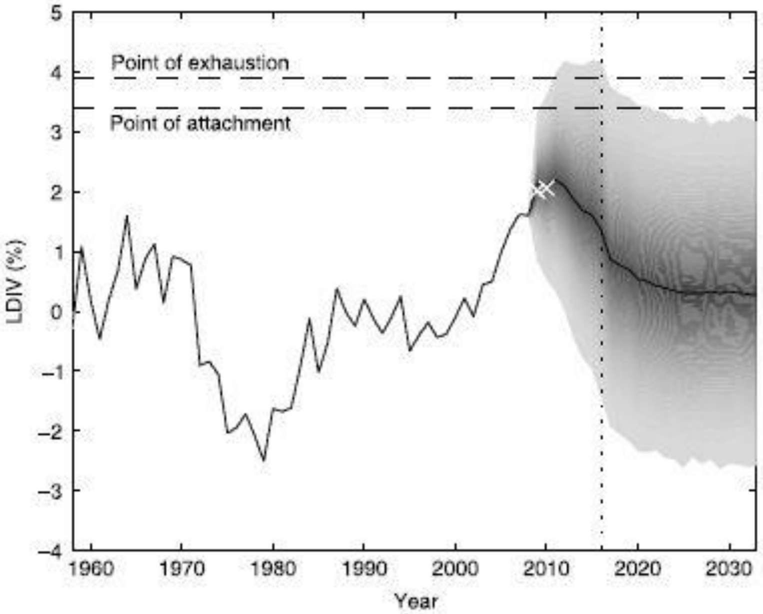
5.2.6 Table 1 shows estimated loss probabilities for the bond using the RMS models. Figure 3 presents a fan chart of the projected LDIV showing the 98% confidence interval.

[29] The payoff of the bond depends on population mortality data for 2016 for England & Wales (now published) and the US (not yet published at the time of writing).
[30] See Section 9.4 for more details.

Table 1: Estimated Loss Probabilities for the Swiss Re Longevity-Spread Bond

LDIV	PRF	Exceedance probability
3.4%	0%	5.31%[(1)]
3.5%	20%	4.32%
3.6%	40%	3.48%
3.7%	60%	2.82%
3.8%	80%	2.28%
3.9%	100%	1.81%[(2)]
Expected loss	3.27%	
Note: [(1)] attachment probability, [(2)] exhaustion probability		
Source: Standard & Poor's (2010) *Presale information: Kortis Capital Ltd*. Tech. Report.		

Figure 3: Fan Chart of the Projected LDIV Showing the 98% Confidence Interval



Source: Hunt and Blake (2015, Figure 8)

5.2.7 In exchange for putting their capital at risk, investors receive quarterly coupons equal to three-month LIBOR plus a margin. This was the first time that the risk of individuals living longer than expected has been traded in the form of a bond. Investors had been reluctant to hold longevity risk long term, but short-term bonds might make holding the risk more acceptable. The bond therefore represented a significant breakthrough for capital market solutions. Nevertheless, there appears to have been very little trading in the bond and no further examples of the bond have so far been issued.

5.3 Capital-Markets-Based Longevity swaps

5.3.1 The first capital-markets-based longevity swap took place in July 2008 between J.P. Morgan and Canada Life in the UK (Trading Risk, 2008). The contract was a 40-year maturity

£500m longevity swap that was linked to the actual mortality experience of the 125,000-plus annuitants in the annuity portfolio that was being hedged. This transaction brought capital markets investors into the longevity market for the very first time, as the longevity risk was passed from Canada Life to J.P. Morgan and then directly on to investors.

5.3.2 This has become the archetypal longevity swap upon which other transactions are based. Insurance companies, such as Rothesay Life, have adapted its structure and collateralization terms to an insurance format.

5.3.3 It is important to note that the J.P. Morgan – Canada Life swap was a customized swap, since it was linked to the actual mortality experience of the hedger. All insurance-based longevity swaps in the UK have also been customized swaps to date. However, such swaps are harder to price and are potentially more illiquid than index-based swaps which are based on the mortality experience of a reference population, such as the national population. Most longevity swaps sold into the capital markets are index-based. These issues are discussed in more detail in Section 8.

5.4 q-Forwards (or Mortality Forwards)

5.4.1 A mortality forward rate contract is referred to as a '*q*-forward' because the letter '*q*' is the standard actuarial symbol for a mortality rate. It is the simplest type of instrument for hedging longevity (and mortality) risk (Coughlan *et al.*, 2007b).[31, 32]

5.4.2 The first capital markets transaction involving a *q*-forward took place in January 2008. The hedger was buy-out company Lucida (Lucida, 2008; Symmons, 2008). The *q*-forward was linked to a longevity index based on England & Wales national male mortality for a range of different ages. The hedge was provided by J.P. Morgan and was novel not just because it involved a longevity index and a new kind of product, but also because it was designed as a hedge of value rather than a hedge of cash flow. In other words, it hedged the value of an annuity liability, not the actual individual annuity payments.

5.4.3 Formally, a *q*-forward is a contract between two parties in which they agree to exchange an amount proportional to the actual realized mortality rate of a given population (or sub-population), in return for an amount proportional to a fixed mortality rate that has been mutually agreed at inception to be payable at a future date (the maturity of the contract). In this sense, a *q*-forward is a swap that exchanges fixed mortality for the realized mortality at maturity, as illustrated in Figure 4. The variable used to settle the contract is the realized mortality rate for that population in a future period. In the case of hedging longevity risk in a pension plan using a *q*-forward, the pension plan will receive the fixed mortality rate and pay the realized mortality

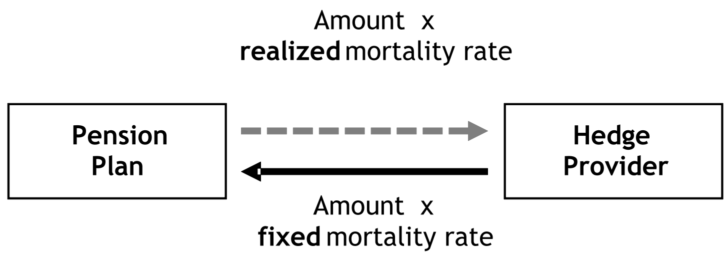
---

[31] See also: http://www.llma.org/files/documents/Technical_Note_q_Forward_Final.pdf; http://www.llma.org/files/documents/SampleTermSheet_-_q-Forward_Final.pdf; http://www.llma.org/files/documents/q-forward_Example_Sheet_Version_Update.xlsm

[32] A related contract is the '*S*-forward' or 'Survivor' forward contract, which is based on the survivor index, $S(t,x)$, which itself is derived from the more fundamental mortality rates.. An '*S*-forward' is the basic building block of a longevity (survivor) swap first discussed in Dowd (2003). A longevity swap is composed of a stream of *S*-forwards with different maturity dates. See: http://www.llma.org/files/documents/Technical_Note_S_Forward_Final.pdf; http://www.llma.org/files/documents/SampleTermSheet_-_S-Forward_Final.pdf; http://www.llma.org/files/documents/S-forward_Example_Sheet_Version_Update.xlsm

rate (and hence locks in the future mortality rate it has to pay whatever happens to actual rates). The counterparty to this transaction, typically an investment bank, has the opposite exposure, paying the fixed mortality rate and receiving the realized rate.

Figure 4: A *q*-Forward Exchanges Fixed Mortality for Realized Mortality at the Maturity of the Contract



Source: Coughlan et al. (2007b, Figure 1)

5.4.4 The fixed mortality rate at which the transaction takes place defines the 'forward mortality rate' for the population in question. If the *q*-forward is fairly priced, no payment changes hands at the inception of the trade, but at maturity, a net payment will be made by one of the two parties (unless the fixed and actual mortality rates happen to be the same). The settlement that takes place at maturity is based on the net amount payable and is proportional to the difference between the fixed mortality rate (the transacted forward rate) and the realized reference rate. If the reference rate in the reference year is below the fixed rate (implying lower mortality than predicted), then the settlement is positive, and the pension plan receives the settlement payment to offset the increase in its liability value. If, on the other hand, the reference rate is above the fixed rate (implying higher mortality than predicted), then the settlement is negative and the pension plan makes the settlement payment to the hedge provider, which will be offset by the fall in the value of its liabilities. In this way, the net liability value is hedged regardless of what happens to mortality rates. The plan is protected from unexpected changes in mortality rates.

5.4.5 Table 2 presents an illustrative term sheet for a *q*-forward transaction, based on a reference population of 65-year-old males from England & Wales. The *q*-forward payout depends on the value of the LifeMetrics Index for the reference population on the maturity date of the contract. The particular transaction shown is a 10-year *q*-forward contract starting on 31 December 2008 and maturing on 31 December 2018. It is being used by ABC Pension Fund to hedge its longevity risk over this period; the hedge provider is J. P. Morgan. The hedge is a 'directional hedge' and will help the pension fund hedge its longevity risk so long as the mortality experience of the pension fund and the index change in the same direction.

5.4.6 On the maturity date, J. P. Morgan (the fixed-rate payer or seller of longevity risk protection) pays ABC Pension Fund (the floating-rate payer or buyer of longevity risk protection) an amount related to the pre-agreed fixed mortality rate of 1.2000 percent (i.e., the agreed forward mortality rate for 65-year-old English & Welsh males for 2018). In return, ABC Pension Fund pays J. P. Morgan an amount related to the reference rate on the maturity date. The reference rate is the most recently available value of the LifeMetrics Index. Settlement on 31 December 2018 will therefore be based on the LifeMetrics Index value for the reference year 2017, on account of the ten-month lag in the availability of official data. The settlement amount is the difference between the fixed amount (which depends on the agreed forward rate) and the floating amount (which depends on the realized reference rate).

Table 2: An Illustrative Term Sheet for a Single *q*-forward to Hedge Longevity Risk

Notional amount	GBP 50,000,000
Trade date	31 Dec 2008
Effective date	31 Dec 2008
Maturity date	31 Dec 2018
Reference year	2017
Fixed rate	1.2000%
Fixed amount payer	J. P. Morgan
Fixed amount	Notional Amount x Fixed Rate x 100
Reference rate	LifeMetrics graduated initial mortality rate for 65-year-old males in the reference year for England & Wales national population Bloomberg ticker: LMQMEW65 Index <GO>
Floating amount payer	ABC Pension Fund
Floating amount	Notional Amount x Reference Rate x 100
Settlement	Net settlement = Fixed amount – Floating amount

Source: Coughlan *et al.* (2007b, Table 1).

5.4.7 Table 3 shows the settlement amounts for four realized values of the reference rate and a notional contract size of £50m. If the reference rate in 2017 is lower than the fixed rate (implying lower mortality than anticipated at the start of the contract), the settlement amount is positive and ABC Pension Fund receives a payment from J. P. Morgan that it can use to offset the increase in its pension liabilities. If the reference rate exceeds the fixed rate (implying higher mortality than anticipated at the start of the contract), the settlement amount is negative and ABC Pension Fund makes a payment to J. P. Morgan which will be offset by the fall in its pension liabilities.

Table 3: An Illustration of *q*-Forward Settlement for Various Outcomes of the Realized Reference Rate

Reference rate (Realized rate)	*Fixed rate*	*Notional (GBP)*	*Settlement (GBP)*
1.0000%	1.2000%	50,000,000	10,000,000
1.1000%	1.2000%	50,000,000	5,000,000
1.2000%	1.2000%	50,000,000	0
1.3000%	1.2000%	50,000,000	-5,000,000

Source: Coughlan *et al.* (2007b, Table 1): A positive (negative) settlement means the hedger pays (receives) the net settlement amount.

5.4.8 It is important to note that the hedge illustrated here is structured as a 'value hedge', rather than as a 'cash flow hedge'. A value hedge hedges the value of the hedger's liabilities at the maturity date of the swap. So although the swap has a duration of only 10 years, it nevertheless hedges that portion of the longevity risk in the hedger's cash flows beyond 10 years that can be crystallized at time 10. This is achieved by exchanging a single payment at maturity. By contrast, a cash flow hedge hedges the longevity risk in each one of the hedger's cash flows and net payments are made period by period as in Figure 2. The J. P. Morgan-Canada Life longevity swap is an example of a cash flow hedge, while the J. P. Morgan-Lucida *q*-forward is an example of a value hedge. The capital markets are more familiar with value hedges, whereas cash flow hedges are more common in the insurance world. Value hedges are particularly suited to hedging the longevity risk of younger members of a pension plan, since it is much harder to estimate with precision the pension payments they will receive when they eventually retire. The world's first swap for non-pensioners (i.e., involving deferred members) took place in January 2011 when J. P. Morgan executed a value hedge in the form of a 10-year *q*-forward contract with the Pall (UK) pension fund.

5.4.9 The importance of *q*-forwards rests in the fact that they form basic building blocks from which other, more complex, life-related derivatives can be constructed. When appropriately designed, a portfolio of *q*-forwards can be used to replicate and to hedge the longevity exposure of an annuity or a pension liability, or to hedge the mortality exposure of a life assurance book. We can demonstrate this as follows.

5.4.10 A series of *q*-forward contracts, with different ages, can be combined to hedge, approximately, a longevity swap. As an example, suppose the contract involves swapping at time t a fixed cashflow, $\hat{S}(t)$, for the realized survivor index, $S(t,x)$, where x is the age at the inception of the swap. The fixed leg can be hedged using zero-coupon fixed-income bonds. The floating leg can be hedged approximately as follows. First, note that we can approximate the survivor index by expanding the cashflow in terms of the fixed legs of a set of *q*-forwards and their ultimate net payoffs (see Cairns et al., 2008):

$$
\begin{aligned}
S(t,x) &= \left(1-q(0,x)\right)\times\left(1-q(1,x+1)\right)\times\ldots\times\left(1-q(t-1,x+t-1)\right) \\
&= \prod_{i=0}^{t-1}\left(1-q_F(0,i,x+i)-\Delta(i,x+i)\right) \\
&\approx \prod_{i=0}^{t-1}\left(1-q_F(0,i,x+i)\right) \\
&\qquad -\sum_{i=0}^{t-1}\Delta(i,x+i)\prod_{j=0,\, j\neq i}^{t-1}\left(1-q_F(0,j,x+j)\right)
\end{aligned}
$$

where $\Delta(i,x+i)=q(i,x+i)-q_F(0,i,x+i)$ and $q_F(0,i,x+i)$ = *q*-forward mortality rate (the fixed rate). Here, $\Delta(i,x+i)$ is the net payoff on the *q*-forward per unit at time $i+1$.

5.4.11 It follows that an approximate hedge (assuming interest rates are constant and equal to r per annum) for $S(t,x)$ can be achieved by holding:

- $-(1+r)^{-(t-1)}\prod_{j=0,\,j\neq 0}^{t-1}\left(1-q_F(0,j,x+j)\right)$ units of the 1-year *q*-forward;
- $-(1+r)^{-(t-2)}\prod_{j=0,\,j\neq 1}^{t-1}\left(1-q_F(0,j,x+j)\right)$ units of the 2-year *q*-forward;
- …

- $-\prod_{j=0,\, j\neq t-1}^{t-1}\left(1-q_F\left(0, j, x+j\right)\right)$ units of the *t*-year *q*-forward.

5.4.12 In calculating these hedge quantities, we take account of the fact that, for example, the payoff at time 1 on the 1-year *q*-forward will be rolled up to time *t* at the risk-free rate of interest. Hence, the required payoff at time *t* needs to be multiplied by the discount factor $\left(1+r\right)^{-(t-1)}$. In a stochastic interest environment, a quanto derivative would be required. This is one that delivers a number of units, *N*, of a specified asset, where *N* is derived from a reference index that is different from the asset being delivered. In this context, *N* equals $-\Delta\left(i, x+i\right)\prod_{j=0,\, j\neq i}^{t-1}\left(1-q_F\left(0, j, x+j\right)\right)$, and we deliver, at time $i+1$, *N* units of the fixed-interest zero-coupon bond maturing at time *t*, with a price $P\left(i+1, t\right)$ at time $i+1$ per unit.

5.5 Tail-risk Protection (or Longevity Bull Call Spread)

5.5.1 To date there have been at least five publicly announced deals involving tail risk protection. The first two involved Aegon: one in 2012 was executed by Deutsche Bank and another in 2013 by Société Générale. The second two involved Delta Lloyd and RGA Re in 2014 and 2015, respectively. The most recent occurred in December 2017 between NN Life and Hannover Re and is similar to the Société Générale deal discussed below.

5.5.2 Société Générale's tail risk protection structure was described in Michaelson and Mulholland (2015).[33] It is an index-based hedge using national population mortality data, but with minimal basis risk (see Section 6.3), and is designed around the following set of principles (p.30-31):

> *In general, capital markets will be most effective in providing capital against the most remote pieces of longevity risk, called tail risk. This can be accomplished by creating 'out-of-the-money' hedges against extreme longevity outcomes featuring option-like payouts that will occur if certain predefined thresholds are breached. These hedges would be capable of alleviating certain capital requirements to which the (re)insurers are subject, thereby enabling additional risk assumption.*
>
> *However, a well-constructed hedge programme must perform a delicate balancing act to be effective. On the one hand, it must provide an exposure that sufficiently mimics the performance of the underlying portfolio so as not to introduce unacceptable amounts of basis risk; while, on the other hand, it must simplify the modelling and underwriting process to a level that is manageable by a broad base of investors. Further, the hedge transaction must compress the 60+ year duration of the underlying retirement obligations to an investment horizon that is appealing to institutional investors.*

5.5.3 Basis risk[34] will reduce hedge effectiveness and this will, in turn, reduce the allowable regulatory capital relief. However, basis risk can be minimized if the hedger can customize three features of the hedge exposure:

- The hedger is able to select the age and gender of the 'cohorts' (also known as model points) they want in the reference exposure. For example, the hedger selects an

[33] See, also, Cairns and El Boukfaoui (2017) for a more detailed description.
[34] See Section 6.3.

exposure totalling 70 cohorts – males and females aged 65–99 – to cover all the retired lives in the pension plan.

- The hedger is able to choose the 'exposure vector', i.e., the 'relative weighting' of each cohort over time. This will equal the anticipated annuity payments for each cohort in each year of the risk period (see Table 4 for an example).

- The hedger is able to select an 'experience ratio matrix', based on an experience study of its underlying book of business. For each cohort, in each year of the risk period, a fixed adjustment is applied to the national-population mortality rate to adjust for anticipated differences between the mortality profile of the hedger's book of business and the corresponding reference population. So if the hedger's underlying lives are healthier than the general population, they will assign experience ratios of less than 100% to 'scale down' the mortality rate applied in the payout (see Table 5 for an example).

Table 4: Exposure Vector: Relative Weighting of Cohorts Over Time

Cohort	*Year 1*	*Year 2*	*Year 3*	...	*Year 15*	*Year 16*	*Year 17*	...	*Year 54*	*Year 55*
Male 65	1000	995	985	…	590	565	535	…	65	55
Male 66	980	975	960	…	505	485	450	…	45	40
…	…	…	…	…	…	…	…	…	…	…
Female 99	125	120	115	…	20	10	5	…	0	0

Source: Michaelson and Mulholland (2015, Exhibit 1).

Table 5: Experience Ratio Matrix

Cohort	*Year 1*	*Year 2*	*Year 3*	...	*Year 15*	*Year 16*	*Year 17*	...	*Year 54*	*Year 55*
Male 65	90%	89%	88%	…	81%	80%	80%	…	75%	75%
Male 66	89%	88%	87%	…	80%	79%	79%	…	75%	75%
…	…	…	…	…	…	…	…	…	…	…
Female 99	77%	77%	76%	…	75%	75%	75%	…	75%	75%

Source: Michaelson and Mulholland (2015, Exhibit 2).

5.5.4 A risk exposure period of 55 years – as shown in Tables 4 and 5 – is unattractive to capital markets investors for a number of reasons. Liquidity in this market is still low and would be completely absent at these horizons. The maximum effective investment horizon is no more than 15 years. Just as important, the risks are too great. The likely advances in medical science suggests that the range of outcomes for longevity experience will be very wide for an investment horizon of more than half a century.

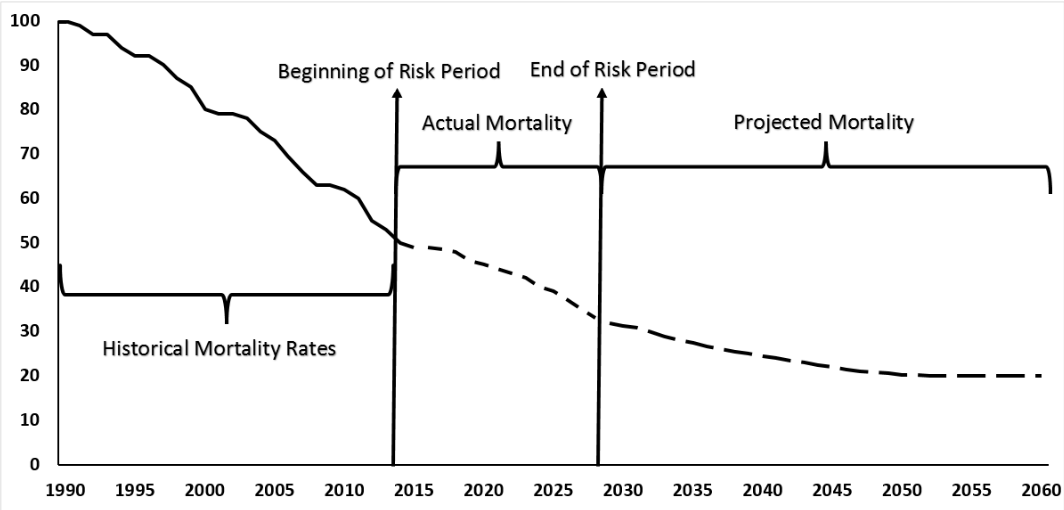
5.5.5 To accommodate both an 'exposure period' of 55 years or more and a 'risk period' (or transaction length) of 15 years, the hedge programme uses a 'commutation function' to 'compress' the risk period. According to Michaelson and Mulholland (2015, pp.32-33):

> *This is accomplished by basing the final index calculations on the combination of two elements: (i) the actual mortality experience, as published by the national statistical reporting agency, applied to the exposure defined for the risk period; and (ii) the present value of the remaining exposure at the end of the risk period calculated using a 're-parameterized' longevity model that takes into account the realized mortality experience over the life of the transaction. This re-parameterization process involves:*
>
> - *Selecting an appropriate longevity risk model and establishing the initial parameterization of the model using publicly available historical mortality data that exist as of the trade date. For a basic longevity model, the parameters that may be established, on a cohort-by-cohort basis, are (i) the current rate of mortality; (ii) the expected path of mortality improvement; and (iii) the variability in the expected path of mortality improvement.*
>
> - *'Freezing' the longevity risk model, with regard to the related structure; but also defining, in advance, an objective process for updating the model's parameters based on the additional mortality experience that will be reported over the risk period. A determination needs to be made as to which parameters are subject to updating, as well as the relative importance that will be placed on the historical data versus the data received during the risk period.*
>
> - *Re-parameterizing the longevity model by incorporating the additional mortality data reported over the life of the trade. This occurs at the end of the transaction risk period, once the mortality data for the final year in the risk period have been received.*
>
> - *Calculating the present value of the remaining exposure using the re-parameterized version of the initial longevity model. This is done by projecting future mortality rates, either stochastically or deterministically, and then discounting the cash flows using forward rates determined at the inception of the transaction.*

5.5.6 The benefit of this approach to the hedger is that 'roll risk'[35] is reduced, since, by taking account of actual mortality rates over the risk period, there will be a much more reliable estimate at the end of the risk period of the expected net present value of the remaining exposure than if only historical mortality rates prior to the risk period were used. The benefit to the investor is that the longevity model is known and not subject to change, so the only source of cash flow uncertainty in the hedge is the realization of national population mortality rates over the risk period – see Figure 5.

[35] This is the risk that arises when a hedger is not able for some reason to put on a single hedge that covers the full term of its risk exposure and is forced to use a sequence of shorter term hedges which are rolled over when each hedge matures, with the risk that the next hedge in the sequence is set up on less favourable terms than the previous one.

Figure 5: Mortality Rates Before, During and After the Risk Period



Note: Projected mortality rates are calculated using experience data available at end of the risk period.
Source: Michaelson and Mulholland (2015, Exhibit 3)

5.5.7 The hedge itself is structured using a long out-of-the money call option bull spread on future mortality outcomes. The spread has two strike prices or, using insurance terminology, an attachment point and an exhaustion point.[36] These strikes are defined relative to the distribution of 'final index values' calculated using the agreed longevity model. The final index value will be a combination of:

- The 'actual' mortality experience of the hedger throughout the risk period which is calculated by applying the reported national population mortality rates to the predefined 'exposure vector' and 'experience ratio matrix' for each cohort in each year of the risk period, and accumulating with interest, using forward interest rates defined on the trade date.

- The 'commutation calculation' which estimates the expected net present value of the remaining exposure at the end of the risk period, calculated using the re-parameterized version of the initial longevity model.

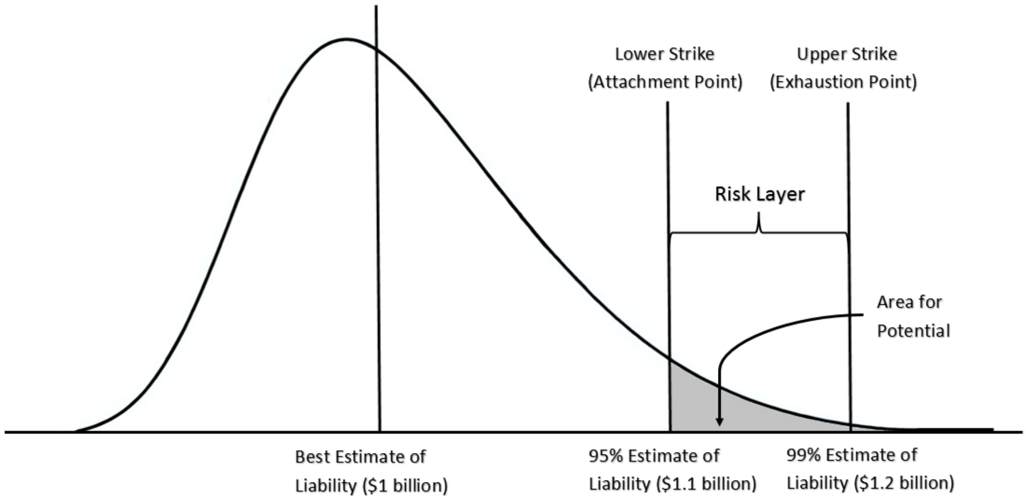
5.5.8 Given the distribution of the final index, the attachment and exhaustion points are selected to maximize the hedger's capital relief, taking into account the investors' (i.e., risk takers') wish to maximize the premium for the risk level assumed. Investors might also demand a 'minimum premium' to engage in the transaction. The intermediary – e.g., the investment bank – therefore needs to carefully work out the optimal amount of risk transfer, given both the hedger's strategic objectives and investor preferences.

5.5.9 The hedger then needs to calculate the level of capital required to cover possible longevity outcomes with a specified degree of confidence. For example, if the 'best estimate' of the longevity liability is $1bn, the (re)insurer may actually be required to hold $1.2bn, $200m of which is reserve capital to cover the potential increase in liability due to unanticipated longevity improvement with 99% confidence.

[36] The spread is constructed using a long call at the lower strike price and a short call at the upper strike price.

5.5.10 The (re)insurer may then decide to implement a hedge transaction with a maximum payout of $100m. This transaction would begin making a payment to the hedger in the event the attachment point is breached, and then paying linearly up to $100m if the longevity outcome meets or exceeds the exhaustion point. This hedge provides a form of 'contingent capital' from investors, enabling the hedger to reduce the amount of regulatory capital it must hold – see Figure 6.

Figure 6: Distribution of the Final Index Value and the Potential for Capital Reduction



Source: Michaelson and Mulholland (2015, Exhibit 3) – not drawn to scale

5.5.11 Tail risk protection was actually discussed in *Living with Mortality* in Section 6.4 entitled 'Geared Longevity Bonds and Longevity Spreads', which we reproduce here. The geared longevity bond enables holders to increase hedging impact for any given capital outlay.

5.5.12 One way to construct such a bond would be as follows. Looking ahead from time 0, the payment on each date t can in theory range from 0 to 1 (times the initial coupon). However, again looking ahead from time 0, we can also suppose that the payment at time t (the survivor index, $S(t,x)$; see paragraph 5.4.10 above) is *likely* to fall within a much narrower band, say $S(t,x) \in [S_l(t), S_u(t)]$. For example, if we are using a stochastic mortality model we could let $S_l(t)$ and $S_u(t)$ be the 2.5% and 97.5% percentiles of the simulated distribution of $S(t,x)$. These simulated confidence limits become part of the contract specification at time 0.

5.5.13 We now set up a special purpose vehicle (SPV) at time 0 that holds $S_u(t) - S_l(t)$ units of the fixed interest zero-coupon bond that matures at time t for each $t = 1, \ldots, T$ (or its equivalent using floating-rate debt and an interest-rate swap). Suppose the SPV is financed by two investors A and B. At time t, the SPV pays: (i) $S(t,x) - S_l(t)$ to A with a minimum of 0 and a maximum of $S_u(t) - S_l(t)$; and (ii) $S_u(t) - S(t,x)$ to B with a minimum of 0 and a maximum of $S_u(t) - S_l(t)$.

5.5.14 The minimum and maximum payouts at each time to A and B ensure that the payments are always non-negative and can be financed entirely from the proceeds of the fixed-interest zero-coupon bond holdings of the SPV.

5.5.15 The payoff at t to A can equivalently be written as $\left(S(t,x)-S_l(t)\right)+\max\left\{S_l(t)-S(t,x),0\right\}-\max\left\{S(t,x)-S_u(t),0\right\}$: that is, a combination of a long forward contract, a long put option on $S(t,x)$ (or a 'floorlet'), and a short call on $S(t,x)$ (or a 'caplet'). The bond as a whole, therefore, is a combination of forwards, floorlets and caplets. Continuing with the option terminology, we can also observe that the payoff to investor A is often referred to as a long 'bull call spread', and for this reason we refer to the payoff in the current context as a long 'longevity bull call spread'.

5.5.16 Let us suppose that, for each t, $S_l(t)$ and $S_u(t)$ have been chosen so that the value of the floorlet and the caplet are equal. In this case, the price payable at time 0 by investor A is equal to the sum of the prices of the T forward contracts paying $S(t,x)-S_l(t)$ at times $t=1,\ldots,T$. This is equal to (i) the price for the longevity bond paying $S(t,x)$ at times $t=1,\ldots,T$, minus (ii) the price for the fixed-interest bond paying $S_l(t)$ at times $t=1,\ldots,T$. This structure therefore gives investors a similar exposure to the risks in $S(t,x)$ for a lower initial price. For this reason, we describe the collection of longevity bull spreads as a geared longevity bond.

5.5.17 As an alternative $S_u(t)$ might be set to 1, meaning that the caplet has zero value ($S(t,x)$ cannot be bigger than 1). With this structure, investor A has full protection against unanticipated improvements in longevity, but gives away any benefits from poorer longevity than anticipated.

5.5.18 It is important to note in the above construction that there is a smooth progression in the division of the coupon payments between the counterparties over the range of $S(t,x)$. This is preferable to a contract that has a jump in the amount of the payment as $S(t,x)$ crosses some threshold: as often happens with such contracts as barrier options, arguments can often arise as to whether the particular threshold was crossed or not. Such difficulties are avoided with the smooth progression.

5.5.19 The bond described here is a variation on the Société Générale structure where the payoff at T depends only on the single survivor index $S(T,x)$. In the more general case, the payoff depends on the values of $S(1,x),\ldots,S(T,x)$, and the forecast values at T of $S(T+1,x), S(T+2,x),\ldots$.

6. Index versus Customized Hedges, and Basis Risk

6.1 *Overview*

Lucida and Canada Life implemented two very different kinds of capital markets longevity hedges in 2008. Lucida executed a standardized hedge linked to a population mortality index, whereas Canada Life executed a customized hedge linked to the actual mortality experience of a population of annuitants. Aegon's hedges with Deutsche Bank in 2012 and with Société

Générale in 2013 were also index hedges, but they were designed to minimize the basis risk involved.[37] It is important to understand the differences between index and customized hedges. It is also important to understand, measure and manage the basis risk in index hedges. This, in turn, will have implications for regulatory capital relief.

6.2 Index versus Customized Hedges

6.2.1 Standardized index-based longevity hedges have some advantages over the customized hedges that are currently more familiar to pension funds and annuity providers. In particular, they have the advantages of simplicity, cost and greater potential for liquidity. But they also have obvious disadvantages, principally the fact that they are not perfect hedges and leave a residual basis risk (see Table 6) that requires the index hedge to be carefully calibrated.

Table 6: Standardized Index Hedges vs. Customized Hedges

	Advantages	*Disadvantages*
Standardized index hedge	• Cheaper than customized hedges • Lower set-up/operational costs • Shorter maturity, so lower counterparty credit exposure	• Not a perfect hedge: ○ Basis risk ○ Roll risk ○ Base table estimation risk
Customized hedge	• Exact hedge, so no residual basis risk • Set-and-forget hedge, requires minimal monitoring	• More expensive than standardized hedge • High set-up and operational costs • Poor liquidity • Credit risk: Longer maturity, so larger counterparty credit exposure • Less attractive to investors

Source: Coughlan (2007a)

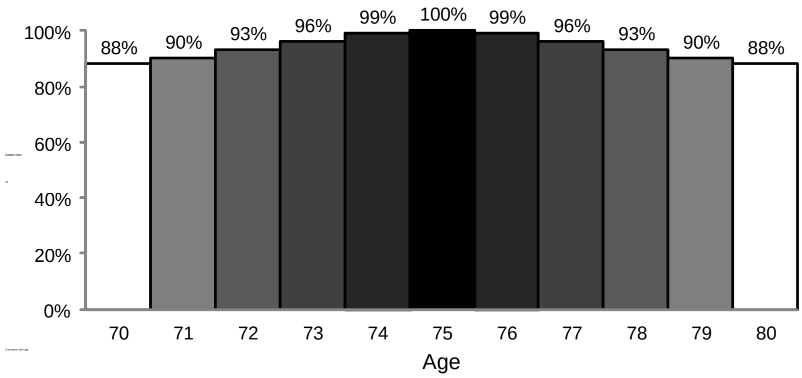
6.2.2 Coughlan *et al.* (2007b) show that a liquid, hedge-effective market could be built around just eight standardized *q*-forward contracts with:

- a specific maturity (e.g., 10 years);
- two genders (male, female);
- four age buckets (50-59, 60-69, 70-79, 80-89).

[37] Aegon had a history of buying up smaller insurance companies all over Holland, so had a well-diversified mortality base that was similar to that of (and therefore highly correlated with) the national population, so the population basis risk in the hedge was minimal.

6.2.3 Figure 7 presents the mortality improvement correlations within the male 70-79 age bucket which is centred on age 75 (Coughlan et al., 2007c). These figures show that the correlations (based on graduated mortality rates) are very high and that contracts based on 75-year-old males will provide good hedge effectiveness for plans with members in the relevant age buckets. Coughlan (2007a) estimates that the hedge effectiveness (of a value hedge) is around 86% (i.e., the standard deviation of the liabilities is reduced by 86%, leaving a residual risk of 14%) for a large and well diversified pension plan or annuity portfolio: see Figure 8.[38]

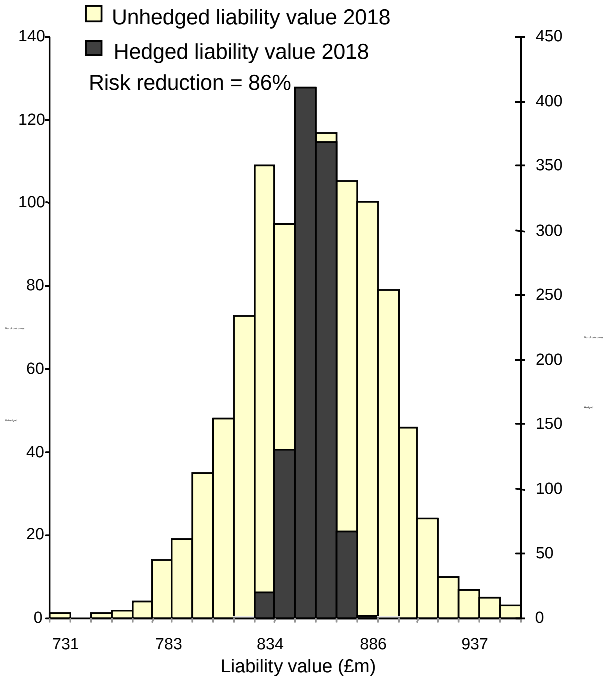
Figure 7: 5-Year Mortality Improvement Correlations
with England & Wales Males Aged 75



Source: Coughlan et al. (2007c, Figure 9.6)

[38] A subsequent study by Coughlan *et al*. (2011) reconfirmed the high degree of effectiveness available with longevity hedges based on national population indices for large pension plans. This study considered a pension fund with a membership whose mortality experience was the same at the UK CMI (Continuous Mortality Investigation) assured lives population; with a hedge based on the England & Wales LifeMetrics Index, hedge effectiveness of 82.4% could be achieved. The same study also considered a pension fund with a membership whose mortality experience was the same at the population of California. With a hedge based on the US LifeMetrics Index, hedge effectiveness of 86.5% could be achieved.

Figure 8: The Hedge Effectiveness of *q*-Forwards



Source: Coughlan (2007a)

6.2.4 In order to keep the number of contracts to a manageable level, individual contracts use the average (or 'bucketed') mortality across 10 ages rather than single ages. This averaging has positive and negative effects. On the one hand, the averaging reduces the basis risk that arises from the non-systematic mortality risk that is present in crude mortality rates, even at the population level.[39] On the other hand, it introduces some basis risk depending on the specific age-structure of the population being hedged. This we now discuss in more detail.

6.3 Basis Risk

6.3.1 Basis risk is the residual risk associated with imperfect hedging where the movements in the underlying exposure are not perfectly correlated with movements in the hedging instrument. Basis risk and its quantification has recently attracted the attention of both academics and practitioners (e.g., Li and Hardy, 2011, Cairns et al., 2013, Longevity Basis Risk Working Group, 2014, Villegas et al., 2017, Cairns and El Boukfaoui, 2017, and Li et al., 2017).

6.3.2 Within the context of longevity risk hedging, a number of sources of basis risk arise: population basis risk; base-table risk; structural risk; restatement risk; and idiosyncratic risk.

6.3.3 Population basis risk is, perhaps, the form of basis risk that most readily comes to mind when considering an index based longevity hedge. Specifically, a hedger might choose to use a hedging instrument that is linked to a different population from its own population that it wishes to hedge. This is most common where the hedging instrument is linked to an index

[39] For example, for England & Wales males, variation in the bucketed *q*-forward payoff that is solely due to non-systematic mortality risk (i.e., sampling variation in the death counts) will have a standard deviation of around 0.3% of the value of the *q*-forward fixed leg. Relative to the uncertainty in the true mortality rate underpinning the *q*-forward payoff with a 10-year horizon, this sampling variation is negligible.

based on national mortality rates, while the hedger's own population is a distinctive sub-population with different characteristics from the national average. As a consequence, *underlying* mortality rates might not just be at a different level from that of the national population, but rates of improvement in both the short and long term might not be perfectly correlated. Modelling and understanding the differences between two populations is an active and rapidly developing subject of research.[40]

6.3.4 Base-table risk concerns how accurately hedgers and also receivers of longevity risk are able to assess the mortality base table for both the hedger's own population and the national population. Whether or not base-table risk contributes to residual risk for the hedger then depends on the nature of the longevity hedge. At one end of the spectrum, from the perspective of the hedger, a customized longevity swap leaves the hedger with no base-table risk, while the receiver is exposed and should charge a higher price to reflect this extra risk. In contrast, for an index-based hedge, base-table risk will be relevant. Base-table risk will then make a more significant contribution to total basis risk if the hedger's own population is small or the time horizon of the hedge is short.

6.3.5 Structural risk relates to the design of the hedging instrument, and it can arise even if there is no population basis risk, or base-table risk.

- The hedging instrument might have a non-linear payoff as a function of the underlying risk. This includes contracts with an option-type payoff structure such as the bull call spread in Michaelson and Mulholland (2015) and Cairns and El Boukfaoui (2017), leaving residual risk both below and above the attachment and exhaustion points. It also includes *q*-forwards: these do not include any optionality, but liability cashflows are typically non-linear combinations of the underlying mortality rates.
- The hedging instrument might have a finite maturity, meaning that the longevity risk that emerges after the maturity date is a residual risk that cannot be hedged.
- The reference ages embedded in the hedging instruments might not allow exact matching of the ages in the hedger's population.
- The number of units of the hedging instrument (i.e., the hedge ratio) might not be optimal (i.e., might not minimize residual risk). This might be either unavoidable or unintentional (e.g., through the use of a poorly calibrated model).

In general, structural risk can be adjusted, for example, through the choice of: attachment and exhaustion points; the maturity date; the reference ages; the number of *q*- or *S*-forwards; and careful calibration and optimisation using the chosen stochastic mortality model.

6.3.6 Restatement risk concerns the possibility that official estimates of the national population or death counts might be revised up or down, with potential impacts on index-based hedge payoffs (Cairns et al., 2016). Restatements, most typically, will impact on previously stated mortality rates (especially following a decennial census), although index-based longevity hedges will probably link contractually to the first announcement of a mortality rate. However, restatements will also have an impact on future estimated population numbers and consequent mortality rates. The future risks and impacts of such restatements can be assessed through use of the same methodology for identifying *phantoms* proposed in Cairns et al. (2016).

[40] Modelling population basis risk is also a key ongoing element of the Institute and Faculty of Actuaries' ARC research programme on 'Modelling Measurement and Management of Longevity and Morbidity Risk' (www.actuaries.org.uk/arc).

6.3.7 Idiosyncratic risk[41] is primarily linked to sampling variation and its financial impact within the hedger's population. As with some other examples of basis risk, the impact of idiosyncratic risk will depend on the nature of the hedge (indemnity versus other forms). Given the evolution of the *systematic* risk in the underlying mortality rates, individuals will either die or survive independently of each other. Proportionately, this risk is larger for smaller pension funds. The level of idiosyncratic risk is also dependent on the heterogeneity in pension amounts (leading to *concentration risk*): for example, a 1000-member pension plan in which 10% of the members are directors (or 'big cheeses') who generate 90% of the liabilities will be more risky than a 1000-member plan with equal pensions.

6.3.8 Finally, as remarked in Cairns (2014), accurate assessment of basis risk is one part of the process of choosing the best hedge. First, one needs to identify the different options for hedging.[42] Second, the risk appetite of the hedger needs to be properly assessed. Third, there needs to be an accurate assessment of the basis risk under each hedge. Fourth, prices need to be established for each hedge. Fifth, the combination of price, basis risk and risk appetite then point to a best choice out of *all* of the options available to the hedger.[43] Cairns (2014) also highlights that no single hedging option is best for all pension plans. Everything else being equal, customized hedges are more likely to be preferred to index hedges by: smaller pension plans rather than larger (due to the greater idiosyncratic risk); and pension plan sponsors that are more risk averse. Also, certain hedging options (e.g., longevity swaps) are only available to pension plans with sufficiently large liabilities.

6.4 Other types of basis risk

Other forms of basis risk might arise if a pension plan seeks to hedge the longevity risk associated with a group of active or deferred members, rather than retired members. These groups bring additional risks, including member options and partner status at retirement and salary risk. The plan's quantum of exposure to longevity risk depends on how these risks turn out, a risk that itself is not hedgeable.

7. 7. CREDIT RISK, REGULATORY CAPITAL, AND COLLATERAL

7.1 Overview

Another risk in Table 6 is counterparty credit risk. This is the risk that one of the counterparties to, say, a longevity swap contract defaults owing money to the other counterparty. When a swap is first initiated, both counterparties might expect a zero profit or loss. But over time, as a result of realized mortality rates deviating from the rates that were forecast at the time the swap started, one counterparty's position will be showing a profit and the other will be showing

[41] That is, randomness in individual lifetimes and financial concentrations associated with a small group of individuals. Everything else being equal, idiosyncratic risks mean that smaller hedgers with greater levels of idiosyncratic risk are more likely to favour customised hedges that transfer the idiosyncratic risks.

[42] Good enterprise risk management means consideration of all of the available options. Although challenging, the administrative costs of carrying out such an exercise is small compared to the potential economic impact of making the right or wrong choice.

[43] Conversely, a hedger's advisors should not let concerns about their own reputational risk influence recommendations: arguably, reputational risk is smaller for indemnity based hedges, and larger for index-based hedges which require higher levels of skill in modelling mortality.

an equivalent loss. The insurance industry addresses this issue via regulatory capital and the capital markets deal with it via collateral.

7.2 Regulatory Capital

7.2.1 The regulatory regime covering insurance companies domiciled in the UK is governed by the Solvency II Directive which came into effect in January 2016 and is used to set regulatory capital requirements.

7.2.2 Regulatory capital is the level of capital or Own Funds required by an insurer's regulatory authority, the PRA in the UK. It is divided into 3 Tiers, reflecting its permanence and ability to absorb losses. Solvency II begins with a calculation of the insurer's liabilities, known as technical provisions, which comprises a 'best estimate' of the liabilities and a risk margin – in the case where the liability cannot be perfectly hedged. The sum of the best estimate plus risk margin is known as the market consistent value or fair value. On top of this, insurers must hold an additional risk-based capital requirement, known as the Solvency Capital Requirement (SCR).

7.2.3 The main objective of Solvency II is to value all assets and liabilities on a market-consistent basis and to ensure that the regulatory capital that insurance companies hold reflects all the unhedged risks on their balance sheets. The capital needs to be sufficient to ensure that an insurance company can survived a series of prescribed stressed events over the course of one year with a 99.5% probability. This can be evaluated using a stochastic internal model (see Section 9) or through the use of the standard stress test, which in the case of longevity risk is a sudden 20% reduction in mortality rates across all ages. For a 65-year old UK male, this corresponds approximately to a 1.5 year increase in life expectancy or a 7% increase in pension liabilities.

7.2.4 A consequence of the market-consistent approach is that both assets and liabilities are more prone to market volatility, although with long-term liabilities, such as annuities and buy-outs, short-term asset price volatility can be partially offset by 'matching adjustments'. The insurer would need to allocate a specific pool of assets to the liability, where the assets are selected to match the cash-flow characteristics of the liability. The assets need to be matched for the entire term of the liability, in which case the liability can be valued using a higher discount rate than prescribed by the PRA, resulting in the insurer holding lower Own Funds to back the liability. However, because of longevity risk, the asset match can never be perfect and this has the effect of raising the level of Own Funds. A particular example is non-pensioner members of pension plans who have greater longevity risk than pensioner members, leading to a lower adjusted discount rate. There is also greater optionality with non-pensioner members (such as early retirement and commutation options) and this also reduces the discount rate and, by raising the level of Own Funds, increases the cost of providing deferred annuities to the pension plan or buying out this segment of the pension plan. Insurance companies increasingly invest in long-term assets like infrastructure and equity release mortgages to reduce asset price volatility, and in corporate bonds to benefit from the credit and illiquidity premia embodied in their higher returns compared with government bonds. They also make increasing use of reinsurance to reduce the volatility of liabilities and hence the level of Own Funds.

7.2.5 One possible implication of Solvency II is that insurers might migrate away from the current cash-flow hedging paradigm towards the value-hedging paradigm. Specifically, insurers might aim to hedge their liability in one year's time as a way to reduce their SCR under Solvency II. This requires comparison of liability and hedge instrument values one year ahead.

7.2.6 Despite Solvency II, some pension plans considering de-risking remain concerned about the financial strength of some insurers, which is why consultants such as Barnett Waddingham have launched an insurer financial strength review service, providing information on an insurer's structure, solvency position, credit rating, and key risks in their business model.

7.2.7 Regulatory capital deals principally with the credit risk of the insurer.[44] The insurer faces credit risk from the pension plan in the case of, say, a longevity swap, and collateral would need to be posted to deal with this.

7.3 Collateral

7.3.1 The role of collateral is to reduce if not entirely eliminate counterparty credit risk in capital market transactions.

7.3.2 Collateral in the form of high quality securities needs to be posted by the loss-making counterparty to cover such losses. However, the collateral needs to be funded and the funding costs will depend on the level of interest rates. Further, the quality of the collateral and the conditions under which a counterparty can substitute one form of collateral for another need to be agreed. This is done in the credit support annex (CSA) to the ISDA Master Agreement that establishes the swap. The CSA also specifies how different types of collateral will be priced.

7.3.3 All these factors are important for determining the value of the swap at different stages in its life. Biffis et al. (2016) use a theoretical model to show that the overall cost of collateralization in mortality or longevity swaps is similar to or lower than those found in the interest-rate swaps market on account of the diversifying effects of interest rate and longevity risks.

8. LIQUIDITY

8.1 Liquidity is another important issue raised in Table 6. The key problem with customized solutions is that they are not liquid and cannot easily be reversed. By contrast, liquidity is a key advantage of well-developed capital market solutions.

8.2 To ensure long-term viability, it is critical that a traded capital market instrument meets the needs of both hedgers and speculators (or traders). The former require hedge effectiveness, while the latter supply liquidity. However, liquidity requires standardized contracts. The fewer the number of standardized contracts traded, the greater the potential liquidity in each contract, but the lower the potential hedge effectiveness. There is therefore an important tradeoff to be made, such that the number of standardized contracts traded provides both adequate hedge effectiveness and adequate liquidity.

8.3 If they are ever to achieve adequate liquidity, it is likely that capital-markets-based solutions will have to adopt mortality indices based on the national population as the primary

[44] It also covers the insurer's underwriting, market and operational risks.

means of transferring longevity risk or sub-population indices that are transparent, trustworthy, reliable and durable. However, potential hedgers, such as life assurers and pension funds, face a longevity risk exposure that is specific to their own policyholders and plan members: for example, it might be concentrated in specific socio-economic groups or in specific individuals such as the sponsoring company's directors. Hedging using population mortality indices means that life assurers and pension funds will face basis risk if their longevity exposure differs from that of the national population. Herein lies the tension between index-based hedges and customized hedges of longevity risk, and, in turn, the unavoidable trade-off between basis risk and liquidity.

8.4 The involvement of the capital markets would help to reduce the cost of managing longevity risk. This is because it should lead to an increase in capacity, together with greater pricing transparency (as a result of the activities of arbitrageurs[45]) and greater liquidity (as a result of the activities of speculators). These conditions should attract the interest of hedge funds, private equity investors, ILS investors, sovereign wealth funds, endowments, family offices and other investors seeking asset classes that have low correlation with existing financial assets. Longevity-linked assets naturally fit this bill.

8.5 Currently, there is still insufficient interest from these classes of investor. However, Figure 1 shows how the market might eventually come into balance, with increasing numbers of potential sellers of longevity risk protection attracted by a suitable risk premium to enter the market to meet the huge demands of potential buyers.

9. MORTALITY MODELS

9.1 Overview

It is clear from the solutions we have described above that mortality models play a critical role in their design and pricing (see, e.g., Figures 3 and 6). There are three classes of stochastic mortality model in use (with some models straddling more than one class):

- extrapolative or time series models;
- process-based models – which examine the biomedical processes that lead to death;
- explanatory or causal models – which use information on factors which are believed to influence mortality rates such as cohort (i.e., year of birth), socio-economic status, lifestyle, geographical location, housing, education, medical advances and infectious diseases.

Most of the models currently in use are in the first of these classes and we will concentrate on these in this section.,

9.2 Extrapolative or time series models – single population variants

9.2.1 There are four classes of time-series-based mortality model in use. First is the Lee-Carter class of models (Lee and Carter, 1992) which makes no assumption about the degree of smoothness in mortality rates across adjacent ages or years. Second is the Cairns-Blake-Dowd (CBD) class of models (Cairns, Blake and Dowd, 2006) which builds in an assumption of

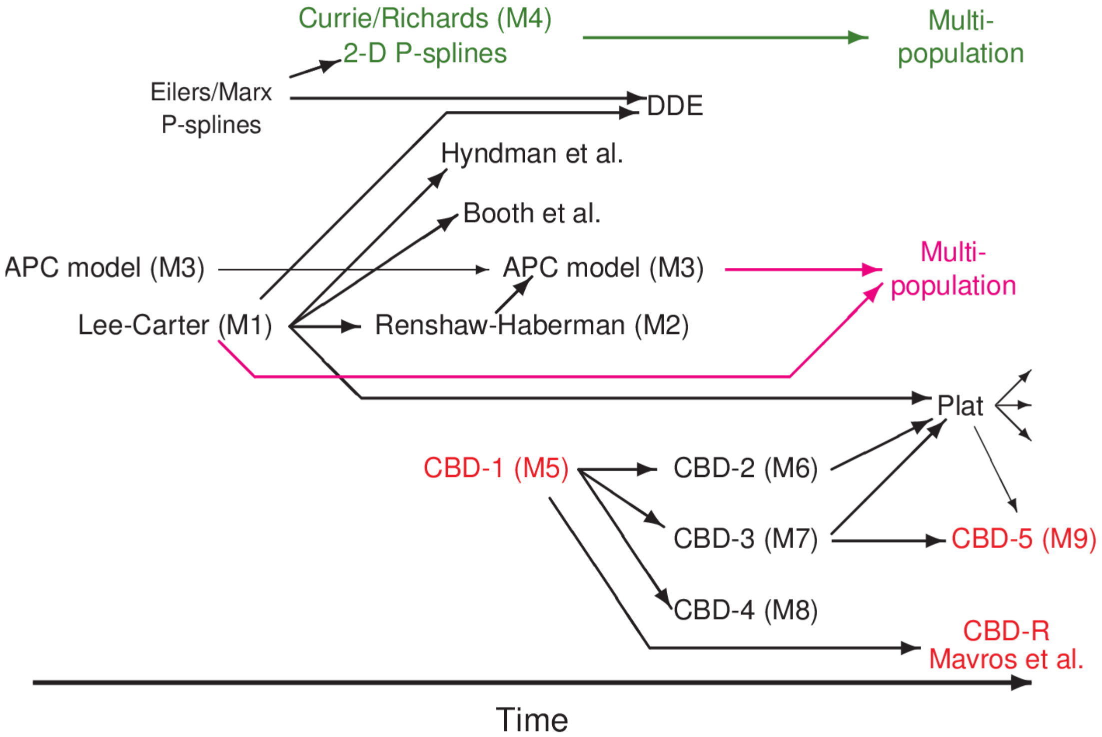
45 However, to be effective, arbitrageurs need well-defined pricing relationships between related securities and we are still at the very early days in the development of this market.

smoothness in mortality rates across adjacent ages in the same year (but not between years).[46] Third is the P-splines model (Currie *et al.*, 2004) which assumes smoothness across both years and ages.[47] Finally, there is the Age-Period-Cohort (APC) model which has its origins in medical statistics (Osmond, 1985; Jacobsen *et al*., 2002), and first introduced in an actuarial context by Renshaw and Haberman (2006). Other features have also jumped from one class to another with the resulting genealogy mapped out in Figure 9. The first two classes of models have also been extended to allow for a cohort effect.[48] All these models were subjected to a rigorous analysis in Cairns *et al.* (2009 and 2011a) and Dowd *et al.* (2010b and 2010c). The models were assessed for their goodness of fit to historical data and for both their *ex-ante* and *ex-post* forecasting properties.

[46] The CBD model was specifically designed for modelling higher age mortality rates. It has recently been generalized to account for the different structure of mortality rates at lower ages by, e.g., Plat (2009) and Hunt and Blake (2014).

[47] Other academic studies of mortality models include Hobcraft et al. (1982), Booth *et al*. (2002a,b), Brouhns *et al*. (2002a,b, 2005), Renshaw and Haberman (2003a,b, 2006, 2008), Biffis (2005), Czado *et al*. (2005), Delwarde *et al*. (2007), Koissi *et al.* (2006), Pedroza (2006), Bauer *et al.* (2008, 2010), Gourieroux and Monfort (2008), Hari *et al.* (2008), Kuang *et al.* (2008), Haberman and Renshaw (2009, 2011, 2012, 2013), Hatzopoulos and Haberman (2009, 2011), Li *et al.* (2009, 2015a), Wang and Preston (2009), Biffis *et al.* (2010), Debonneuil (2010), Lin and Tzeng (2010), Murphy (2010), Yang *et al.* (2010), Coelho and Nunes (2011), D'Amato *et al.* (2011, 2012a,b), Gaille and Sherris (2011), Li and Chan (2011), Milidonis *et al.* (2011), Russo *et al.* (2011), Russolillo *et al.* (2011), Sweeting (2011), Wang *et al.* (2011), Alai and Sherris (2014b), Aleksic and Börger (2012), Hainaut (2012), Hyndman *et al.* (2013), Mitchell *et al.* (2013), Nielsen and Nielsen (2014), Mayhew and Smith (2014), Danesi *at al.* (2015), O'Hare and Li (2015), Berkum *et al.* (2016), Currie (2016), and Richards *et al.* (2017).
~~(2009).~~

Figure 9: A Genealogy of Stochastic Mortality Models



(Source: adapted from Cairns 2014)

9.2.2 Cairns *et al.* (2009) used a set of quantitative and qualitative criteria to assess each model's ability to explain *historical* patterns of mortality: quality of fit, as measured by the Bayes Information Criterion (BIC); ease of implementation; parsimony; transparency; incorporation of cohort effects; ability to produce a non-trivial correlation structure between ages; and robustness of parameter estimates relative to the period of data employed. The study concluded that a version of the CBD model allowing for a cohort effect was found to have the most robust and stable parameter estimates over time using mortality data from both England & Wales and the US. This model (usually referred to as "M7") is now the keystone of one of the two approaches recommended by the Life and Longevity Markets Association (LLMA)[49] (Longevity Basis Risk Working Group, 2014, Villegas et al., 2017, and Li et al., 2017).

9.2.3 Cairns *et al.* (2011a) focused on the qualitative *forecasting* properties of the models[50] by evaluating the *ex-ante* plausibility of their probability density forecasts in terms of the following qualitative criteria: biological reasonableness;[51] the plausibility of predicted levels of uncertainty in forecasts at different ages; and the robustness of the forecasts relative to the sample period used to fit the models. The study found that while a good fit to historical data, as measured by the BIC, is a good starting point, it does not guarantee sensible forecasts. For example, one version of the CBD model allowing for a cohort effect produced such implausible forecasts of US male mortality rates that it could be dismissed as a suitable forecasting model.

[49] www.llma.org
[50] The P-splines model was excluded from the analysis because of its inability to produce fully stochastic projections of future mortality rates.
[51] A method of reasoning used to establish a causal association (or relationship) between two factors that is consistent with existing medical knowledge.

This study also found that the Lee-Carter model produced forecasts at higher ages that were 'too precise', in the sense of having too little uncertainty relative to historical volatility. The problems with these particular models were not evident from simply estimating their parameters: they only became apparent when the models were used for forecasting. The other models (including the APC model) performed well, producing robust and biologically plausible forecasts.

9.2.4 It is also important to examine the *ex post* forecasting performance of the models. This involves conducting both backtesting and goodness-of-fit and analyses. Dowd *et al.* (2010b), undertook the first of these analyses. *Backtesting* is based on the idea that forecast distributions should be compared against subsequently realized mortality outcomes and if the realized outcomes are compatible with their forecasted distributions, then this would suggest that the models that generated them are good ones, and *vice versa*. The study examined four different classes of backtest: those based on the convergence of forecasts through time towards the mortality rate(s) in a given year; those based on the accuracy of forecasts over multiple horizons; those based on the accuracy of forecasts over rolling fixed-length horizons; and those based on formal hypothesis tests that involve comparisons of realized outcomes against forecasts of the relevant densities over specified horizons. The study found that the Lee-Carter model, the APC model and the CBD model (both with and without a cohort effect) performed well most of the time and there was relatively little to choose between them. However, another version of the Lee-Carter model allowing for a cohort effect repeatedly showed evidence of instability.[52]

9.2.5 Dowd *et al.* (2010c) set out a framework for evaluating the *goodness of fit* of stochastic mortality models and applied it to the same models considered by Dowd *et al.* (2010b). The methodology used exploited the structure of each model to obtain various residual series that are predicted to be independently and identically distributed (iid) standard normal under the null hypothesis of model adequacy. Goodness of fit can then be assessed using conventional tests of the predictions of iid standard normality. For the data set considered (English & Welsh male mortality data over ages 64-89 and years 1961-2007), there are some notable differences amongst the various models, but none of the models performs well in all tests and no model clearly dominates the others. In particular, all the models failed to capture long-term changes in the trend in mortality rates. Further development work on these models is therefore needed. It might be the case that there is no single best model and that some models work well in some countries, while others work well in other countries.

9.2.6 The CBD model appears to work well in England & Wales for higher ages, and Figures 10 – 12 present three applications of the model using ONS data for England & Wales.

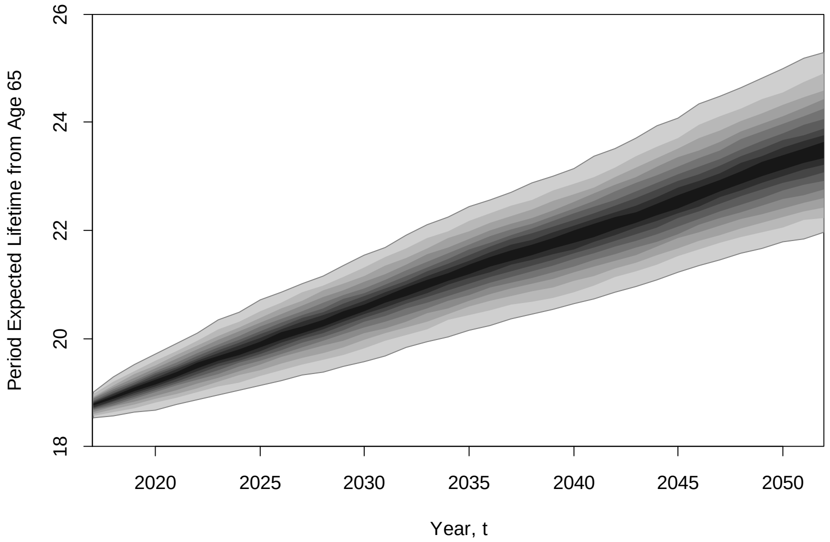
9.2.7 The first (Figure 10) is a longevity fan chart (Dowd et al, 2010a) which shows the increasing funnel of uncertainty concerning future life expectancies out to 2052 of 65-year-old males from England & Wales.[53] By 2047, life expectancy from age 65 is centred around 23 years, shown by the dark central band: an increase of 4 years on the expectation for the year 2017. The different bands within the fan correspond to 5% bands of probability with the lower and upper boundaries at the 5% and 95% quantiles. Adding these together, the whole fan chart shows the 90% confidence interval for the forecast range of outcomes. We can be 90%

[52] See Renshaw and Haberman (2006). This was later explained in terms of a missing identification condition in the model (Hunt and Villegas (2015)).

[53] Note projections run from 2017 based on a variant of the CBD model estimated using data for ages 50-89 and years 1977-2016.

confident that by 2047, the life expectancy of a 65-year-old English & Welsh male will lie between 21.3 and 24.3. This represents a huge range of uncertainty. Since every additional year of life expectancy at age 65 adds around 4 to 5%[54] to the present value of pension liabilities, the cost of providing pensions in 2060 could be 7 to 8% higher than the best estimate for 2047 made in 2017.

Figure 10: Longevity Fan Chart for 65-year-old English & Welsh Males



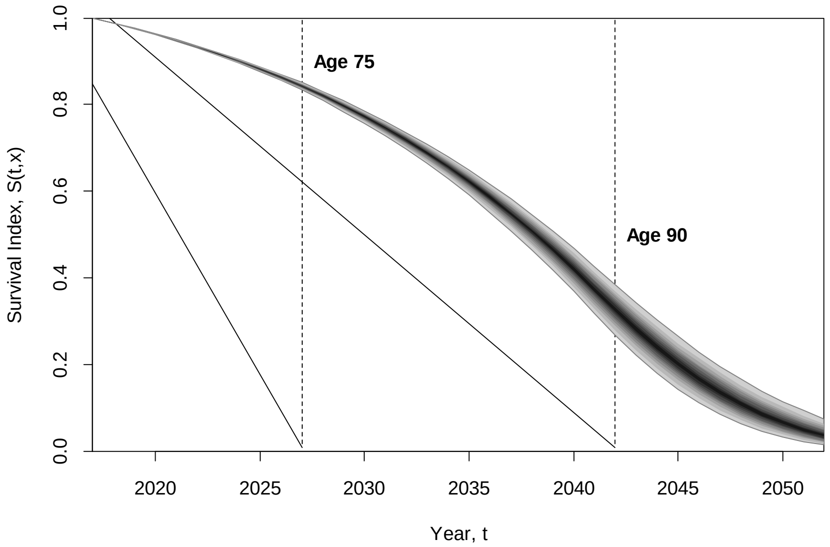
Source: own calculations

9.2.8 The second is a survivor fan chart (Blake et al, 2008) which shows the 90% confidence interval for the survival rates of English & Welsh males who reached 65 at the end of 2016. Figure 11 shows that there is relatively little survivorship risk before age 75: a fairly reliable estimate is that 20% of this group will have died by age 75.[55] The uncertainty increases rapidly after 75 and reaches a maximum just after age 90, when anywhere between 27 and 38 percent of the original cohort will still be alive. We then have the long 'tail' where the remainder of this cohort dies out some time between 2042 and 2062.

[54] See paragraph 2.2.

[55] This is one of the reasons why the EIB/BNP Paribas bond was considered expensive: the first 10 years of cash flows are, in present value terms, the most costly cash flows of a bond, and, in the case of the EIB bond, incorporate a longevity hedge that is not really needed.

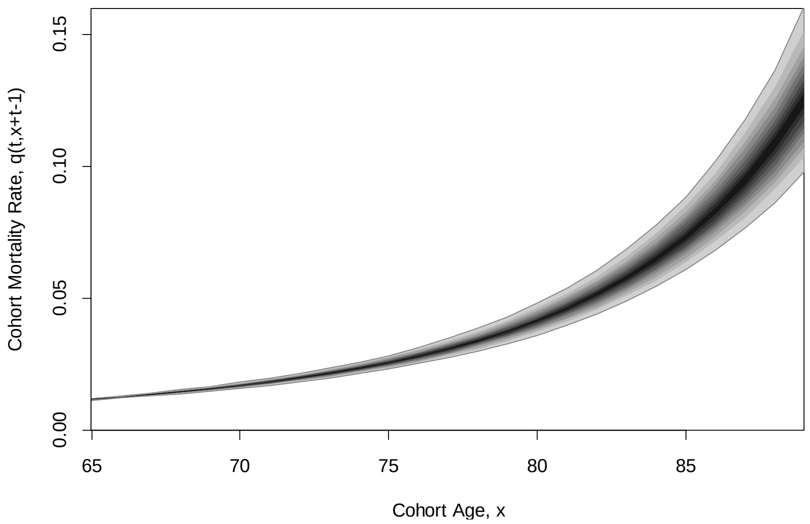
Figure 11: Cohort Survivor Fan Chart for 65-year-old English & Welsh Males



Source: own calculations

9.2.9 The third is a mortality fan chart which shows the 90% confidence interval for 65-year old English & Welsh males who reached 65 at the end of 2016. Figure 12 shows that there is an increasingly low probability of surviving year to year at very high ages, even with predicted mortality improvements.

Figure 12: Cohort Mortality Fan Chart for 65-year-old English & Welsh Males



Source: own calculations

9.2.10 By building off a good mortality forecasting model estimated using data from an objective, transparent and relevant set of mortality indices, fan charts provide a very useful tool for both quantifying and visually understanding longevity, survivor and mortality risks.

9.2.11 One key problem that extrapolative models have is their difficulty in differentiating between a genuine change in the trend of mortality rates and a temporary blip in mortality rates until some time after the change has occurred. In 2016, the UK Office for National Statistics reported that longevity improvements rates have slowed down since 2011, especially at high ages; but it is not yet clear whether this is a genuine change in the long-term trend, a short-term austerity-driven adjustment, or just the result of a purely random deviation from the previous trend.[56] Nevertheless, it prompted a debate in the UK in 2016 about the reliability of life expectancy projections. Mortality improvements in UK males averaged 0.6% p.a. over the preceding four years, compared with 3.2% p.a. in the decade before and 1.5-2% between 1995 and 2000.[57] The UK Continuous Mortality Investigation (CMI) has systematically lowered its estimate of both male and female life expectancy at age 65 every year between 2013 and 2016 as Table 7 shows.

Table 7: UK Life Expectancy at Age 65

Version of the CMI Model	*Male*	*Female*
CMI_2013	22.8 years	25.1 years
CMI_2014	22.8 years	24.9 years
CMI_2015	22.5 years	24.6 years
CMI_2016	22.2 years	24.1 years

Source: Continuous Mortality Investigation

9.2.12 Tim Gordon, head of longevity at Aon Hewitt, said: ‘This is the most extreme reversal in mortality improvement trends seen in the past 40 years. What was initially assumed by many actuaries to be a blip is increasingly looking more like an earlier-than-expected fall-off in mortality improvements. The industry is currently trying to digest all the implications of this emerging information and – inevitably – it is taking time to feed through into insurance and reinsurance pricing’. Others say that this could just be ‘noise’. Matt Wilmington, director of pension risk transfer at L&G, points out that: ‘Two years doesn’t make a trend – it’s very volatile from year to year. If we had another five years where we saw far fewer deaths than expected, then we might start to see fairly significant changes, but where we are now, there’s not enough to persuade us – or many of the pension plans we work with – that there’s a vast reversal in trend in terms of life expectancy just yet’. Tim Gordon also warns against attempts to time the market: ‘Timing the longevity market in the same way you would time an equity market is extremely difficult, and plans could be in danger of missing opportunities now if they did that’.[58] Nevertheless, the difference in mortality improvement rates is equivalent to a difference in liabilities of 1% or four months of pension payments for every retiree: UK pension liabilities would be £25bn lower if the future mortality improvement rate were 1% rather than 3%.[59]

9.2.13 Consultant Barnett Waddingham has put forward the suggestion that higher health and social care spending between 2000 and 2010 may have caused a blip in longevity estimates by

[56] Anthony Hilton (2016) Life line, *Pensions World*, May. See also www.bbc.com/news/health-40608256 .
[57] Own calculations: ages 60-89 covering the periods 2001-2011 (3.2% p.a. improvements) and 2011-2015 (0.6%). Females 2.6% falling to 0.2%.
[58] Quoted in Jenna Gadhavi (2017) Does the bell toll for longevity swaps?, *Engaged Investor*, 13 January.
[59] *Professional Pensions*, 26 January 2017.

accelerating improvements. Since 2009, health spending has been flat in real terms, social care spending has fallen in real terms, and there have been lower mortality improvements.[60]

9.3 Extrapolative or time series models – multiple population variants

9.3.1 There are a number of reasons why it might be appropriate or desirable to model two or more populations simultaneously. First, a pension plan might often be relatively small in relation to the national population; it might have relatively poor quality data (e.g., relatively limited coverage of ages, or only a few calendar years of observations) or simply have a lot of sampling variation. In contrast, many national populations have much better quality data. By modelling the two populations in tandem and exploiting the correlations between the two, we can achieve better quality forecasts for the pension plan. Second, the use of multiple population mortality models allows us to model more accurately the relationships between two or more groups that are directly of interest to us (e.g., males and females; assured lives and annuitants in a life insurer's book of business; life insurance portfolios in different countries etc.). This will lead to better consistency in forecasts as well as, for example, an assessment of the diversification benefits of having less-than-perfectly correlated groups of lives. Third, multiple-population modelling is essential for any institution seeking to hedge its exposure to longevity risk using index-based hedging instruments: the model is required to assess the level of basis risk in the transaction.

9.3.2 The development of multi-population mortality models has lagged single population modelling quite considerably partly due to a lack of good quality sub-population datasets (the CMI assured lives dataset being a notable exception). The Human Mortality Database (HMD) has data for many countries and offers a useful starting point, but sub-population data present particular challenges that are often not present in international data (e.g., shorter runs of data, smaller population sizes etc.). In the demography literature, Li and Lee (2005) laid key foundations: in particular, the principle of *coherence*. The ratio of mortality rates in two populations can and will vary over time. However, the principle of coherence requires that this ratio should not diverge over time to zero or infinity.[61] In the actuarial literature, key early contributions have been made by Cairns et al. (2011b), Dowd et al. (2011), Li and Hardy (2011) and Börger et al. (2013).[62] More recently, Villegas et al. (2017) carried out an extensive review of both existing and potential new multi-population models. Despite the general popularity of the Li and Lee (2005) model, their model has been found to be quite unsuitable for some actuarial applications by both Villegas et al. (2017) and Enchev et al. (2017). Specifically, applications that require a stochastic assessment of longevity risk (e.g., measurement of basis risk or diversification benefits) require models that have a plausible correlation term structure: the Li and Lee model fails this criterion.[63]

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[60] *Professional Pensions*, 29 March 2017.

[61] As an example, the principal of coherence means that male mortality rates should (mostly) remain a bit higher than female mortality in the long run, and not cross over with certainty as can happen if single population models are fitted to each group independently.

[62] See also Jarner and Kryger (2011), Njenga and Sherris (2011), Börger and Ruß (2012), Zhou et al. (2014), Chen et al. (2015), Kleinow (2015), Li et al. (2015b)) and Enchev et al. (2017).

[63] The Li and Lee model commonly predicts perfect correlation between future (log) death rates in two populations at very different ages. Biologically, this is highly implausible.

9.3.3 To satisfy the principle of coherence, Cairns et al. (2011b) make use of a mean-reverting stochastic spread that allows for different trends in mortality improvement rates in the short-run, but parallel improvements in the long run. This study uses a Bayesian framework that allows the estimation of the unobservable state variables that determine mortality and the parameters of the stochastic processes that drive those state variables to be combined into a single step. The key benefits of this include a dampening of the impact of Poisson variation in death counts,[64] full allowance for parameter uncertainty, and the flexibility to deal with missing data.

9.3.4 Dowd *et al.* (2011) employ a 'gravity' model to achieve coherence using an iterative estimation procedure.[65] The larger population is modelled independently (similar to the approach recommended by Villegas et al., 2017), but the smaller population is modelled in terms of spreads (or deviations) relative to the evolution of the larger population. To satisfy the principle of coherence, the spreads in the period and cohort effects between the larger and smaller populations depend on gravity or spread reversion parameters for the two effects. The larger the two gravity parameters, the more strongly the smaller population's mortality rates move in line with those of the larger population in the long run.

9.3.5 In their comprehensive comparison of two-population models, Villegas *et al.* (2017) find that two models satisfy best their criteria for a good two-population model: the common age effect model (Kleinow, 2015) with a cohort effect added; and a variant of the CBD family labelled as M7-M5. Additionally, they offer useful guidance on the minimum quality of data for the sub-population: a minimum annual exposure of 20,000 to 25,000 lives over at least 8 to 10 years, although Bayesian methods offer the potential to relax these criteria somewhat (e.g., Cairns et al., 2011b, 2017a, Chen et al., 2017).

9.4 Process-based and causal models

9.4.1 Until recently, these classes of models were not widely used, since the relationships between biomedical and causal factors and underlying death rates were not sufficiently well understood and because the underlying data needed to build the models were unreliable. This has begun to change.

9.4.2 In 2012, RMS launched a series of mortality indices and models via a platform called RMS LifeRisks. The platform allows life insurance companies and pension funds in the UK, the US, France, Germany, Holland and Canada to model and manage their exposure to longevity and mortality risks, taking into account recent medical research and social change projections. There are two principal models.[66]

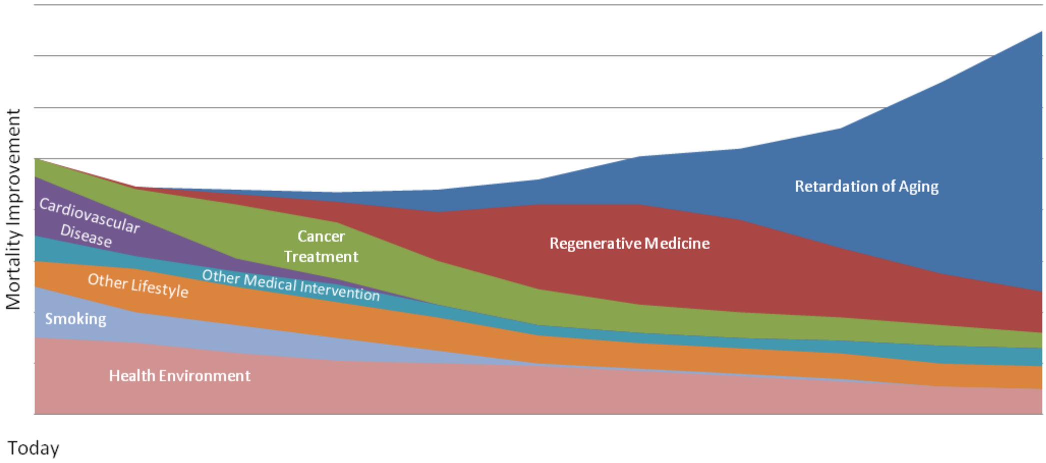
9.4.3 The first model is the RMS Longevity Risk Model. This is the base model used to project mortality and variations in mortality during normal conditions when there are no extreme mortality events. The projections depend on a number of so-called 'vitagion categories' or

[64] The study uses the common assumption that individual deaths follow a Poisson distribution. If one of the populations is relatively small, Chen et al., (2017) show that the standard two-stage maximum likelihood (in contrast to the one-stage Bayesian) approach produces highly biased estimates of the period effect volatilities.
[65] See Hunt and Blake (2018) for a superior set of identification conditions for estimating the gravity model.
[66] It is worth pointing out that, unlike the extrapolative or time series models, the RMS models have never been published or subject to independent peer review.

individual sources of mortality improvement (see Figure 13). The five categories used by RMS are: lifestyle trends including smoking prevalence; health environment; medical intervention; regenerative medicine, such as stem cell research, gene therapy and nanomedicine; and the retardation of ageing, including telomere shortening and caloric restriction.

9.4.4 The second model is the RMS infectious diseases model. This is used to estimate the additional mortality arising from the outbreak of certain infectious diseases, e.g., pandemic influenza. Both models were used in pricing the Kortis bond (see Section 5.2) and an outbreak of something like influenza would be the most likely reason for the attachment point being reached during the life of the bond.[67]

Figure 13: Timeline into the Future



Note: Structural Modelling of medical-based mortality improvement explores the timing, magnitude, and impact of different phases of new medical advances on the horizon. *Source*: RMS (2010) 'Longevity Risk'.

9.4.5 Academic researchers have recently begun experimenting with the introduction of causal variables in their mortality models (e.g., Hanewald, 2011, Gaille and Sherris, 2011, Alai et al.,2014a, Villegas and Haberman, 2014, Gourieroux and Lu, 2015, and Cairns et al., 2017a). Practitioners also started to use post or zip code as a measure of socio-economic class (SEC) in their proprietary mortality models, especially for pricing annuities. An early example is Richards (2008).

9.4.6 In 2008, Club Vita, a UK longevity data and analytics company, was set up with the express purpose of improving the socio-economic modelling of mortality data, allowing the segmentation of projections by SEC. To illustrate, cancer mortality related to smoking (such as larynx, oropharynx, oral cavity and lung) is more commonly associated with the lowest SEC, while cancer mortality related exposure to the sun (malignant melanoma) is more commonly associated with the highest SEC. Segmented longevity trend models have improved in recent years as a result of new insights from medical science and a greater understanding of cause of death for each SEC. The benefits of this to a pension scheme have been a lower best estimate of life expectancy (due to a more accurate socio-economic breakdown of the scheme's membership) and a reduced risk distribution (due to greater certainty about the trends for the different SECs, improved diversification across SECs, and reduced basis risk). The benefits to

[67] See Section 5.2.

an insurer seeking new business have been refined pricing, improved risk selection and increased competitiveness (Baxter and Wooley, 2017)

9.4.7 The emergence of new multi-population datasets with socio-economic subdivisions is also beginning to offer much greater potential for the development of reliable and robust multi-population models. For example, Cairns et al. (2017a) make use of Danish population data subdivided using a measure of *affluence* that combines wealth and income, and utilising this data, they develop a 10-population CBD-type stochastic model over the age range 55 to 94. With 10 sub-populations to analyse, they avoid excessive model complexity by assuming a relatively simple model for correlations between sub-populations. A Bayesian framework is exploited to dampen the effect of sampling variation that is inherent in the 10 relatively small sub-populations. It is anticipated that in the near future this and other datasets will become publicly available to allow researchers to develop alternative models, as well as further road-testing existing models.

10. 10. APPLICATIONS OF THE MORTALITY MODELS

10.1 Overview

In this section, we introduce some applications of the extrapolative mortality models introduced in the previous section: practical implementation of stochastic mortality models; pricing and determination of the longevity risk premium; estimating regulatory capital relief with a hedge in place; and comparison of alternative longevity risk management options. We begin by considering different types of users of these models.

10.2 Users of stochastic mortality models

10.2.1 The following are potential users (directly or indirectly) of stochastic mortality models: insurers and reinsurers; regulators (e.g., the PRA); pension plans (large and small); specialist and general investors; actuaries and actuarial consultants; and software providers (e.g., Longevitas).

10.2.2 Insurers and reinsurers have a variety of reasons for using stochastic mortality models. Arguably, the principal reason is that they form part of an overall package of good enterprise risk management alongside stochastic models for other major risks, all augmented by a range of appropriate stress and scenario tests. Insurers can then use stochastic models to assess their economic capital requirements. Closely linked to this, many insurers are moving towards the use of stochastic models to assess regulatory capital requirements. For example, the PRA strongly encourages the use of stochastic mortality models with the standard one-year horizon under Solvency II (Prudential Regulatory Authority, 2015, 2016). Multi-population models also offer the potential for insurers to assess the diversification benefits resulting from exposure to different portfolios of lives (males/females, smokers/non-smokers, assurances/annuities, multi-country, etc.), with subsequent reductions, for example, in regulatory capital. Lastly, insurers might wish to use stochastic models to compare different options for the management of longevity risk. Depending on in-house capability, insurers might develop their own suite of stochastic mortality models, or use external expertise. This might come in the form of ready-to-use mortality software that is employed in-house by appropriately trained staff, or by contracting external consultants to perform stochastic analyses.

10.2.3 Regulators will not, typically, be direct users of stochastic mortality models. However, they do need to be sufficiently knowledgeable in their use (including awareness of the assumptions and limitations of each model) in order to be able to assess how they are being used by life insurers. Additionally, they need to be able to give periodic guidance on the use of stochastic models, including which models are, or are not, acceptable (see, for example, Prudential Regulatory Authority, 2015, 2016).

10.2.4 The acceptance of systematic longevity risk will, in general, form part of the core risk taking of an insurer up to a level that is consistent with its overall risk appetite. In contrast, acceptance of longevity risk is not generally part of the core business of the typical sponsor of an occupational pension plan (nor indeed is investment and interest-rate risk). Nevertheless, systematic longevity risk is present and therefore requires careful attention. Large pension plans have the resources to assess their exposure to longevity risk through the use of both stochastic modelling and deterministic scenarios: again as part of a wider programme of integrated risk management. As with insurers, this might be done in-house, but more often this would be a service provided by the plan's actuarial advisors. Smaller pension plans are less likely to have the financial resources to carry out a full stochastic assessment of longevity risk. But there is the potential for the longevity risk research community to develop a small range of deterministic longevity scenarios (expressed as adjustments to the preferred best estimate forecast) that capture the essence of realistic extreme stochastic scenarios. These should contrast favourably with the poorly formulated 20% stress test required under Solvency II (see Cairns and El Boukfaoui, 2017). Models, therefore, can help plans determine appropriate target funding levels and contribution rates, as well as assess the risks associated with meeting these targets. Finally, as remarked before, use of stochastic models is recommended as a way to help choose between alternative longevity risk management options (including retention of the risk).

10.2.5 Pension plans also need to assess the potential future funding levels that might result from future uncertain investment returns, interest rate changes and changes in longevity. Stochastic mortality models can be used as part of a larger internal modelling exercise to assess uncertainty in funding levels. Larger plans will have the resources to carry out such an exercise. For smaller plans, stochastic models can be used by actuarial consultants to generate a small number of deterministic, extreme scenarios that can applied to a range of smaller pension plans.

10.2.6 Specialist and general investors in longevity risk (e.g., ILS investors, hedge funds, sovereign wealth funds, endowments and family offices) and other receivers of longevity risk (e.g., reinsurers) are only likely to invest in this risk if class if offered an acceptable risk premium, taking into account the low correlation between longevity risk and financial market risks and hence the potential diversification benefits from including longevity-linked products in an investment portfolio. This will be reflected in the price of the transaction at the outset relative to a best estimate or expected value. A rigorous approach to this requires a stochastic model to assess how much risk there is around the expected payoff. In a competitive market, the size of the risk premium will reflect each potential investor's other exposures: for example, a reinsurer might be satisfied with a lower risk premium for longevity risk if they have offsetting life assurance exposures.

10.3 Practical implementation of stochastic mortality models

10.3.1 It is common practice in the UK to use different methodologies both for setting central forecasts and for risk assessment around that central forecast. For example, life insurers might use the CMI-2016 model (formally known as the CMI mortality projection model, calibrated using data up to 2016) to frame their central forecast and calculate best estimate liabilities. They then follow PRA guidelines (Prudential Regulatory Authority, 2015, 2016) and use stochastic mortality models to assess, proportionately, how much risk there is around that best estimate (Cairns et al., 2017b). The use of CMI-2016 allows users some control over future improvement rates and in key elements requires the exercise of sound judgement (e.g., in setting the long-term rate of improvement). This contrasts with the more objective statistical approach prevalent in stochastic mortality modelling. Under the objective approach, the central forecast is determined by: the choice of model; the choice of time series model (or equivalent) for forecasting period and cohort effects; and the historical calibration period. No further judgement is required.

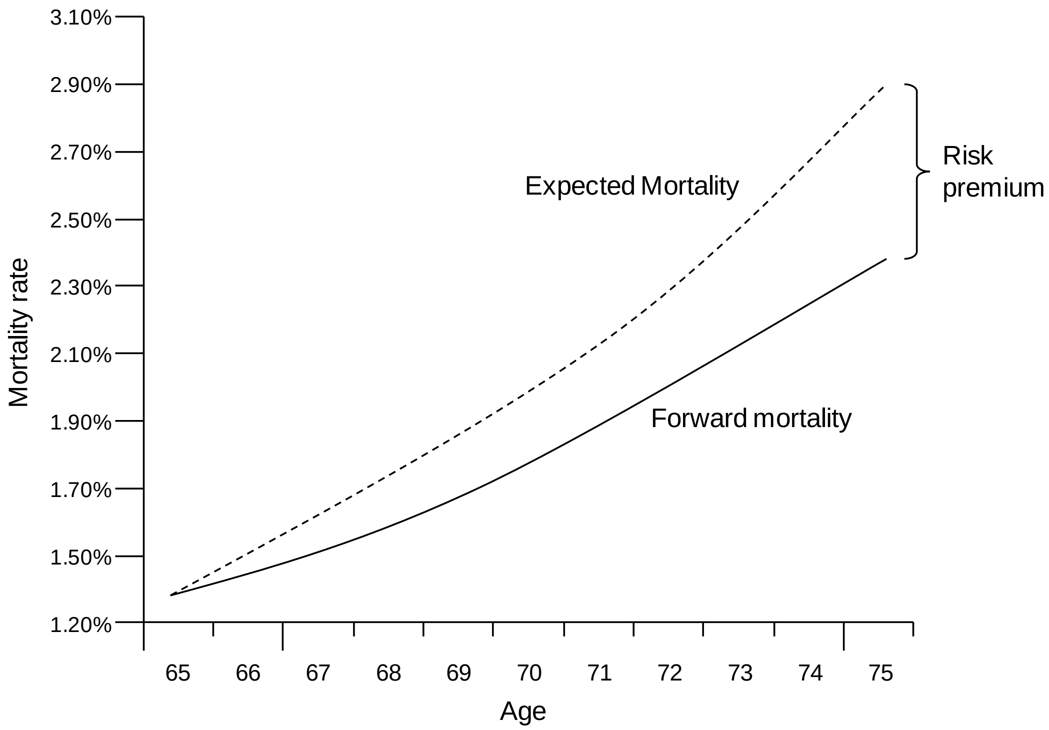
10.3.2 Current research is attempting to close the gap between the two approaches. For example, Richards et al. (2017) focus on the Age Period Cohort Improvements (APCI) model that underpins the historical calibration of the CMI_2016 model, and propose a coherent stochastic approach for forecasting. On the other hand, Cairns et al. (2017b) discuss an approach that closes the gap between the CMI central forecast and the mean trajectory under the objective statistical approach. This involves giving the user some control over setting the short and long term central trends in the period and cohort effects in a stochastic model. With some minor constraints applied to the historical calibration of the CMI model, the adapted stochastic model and the CMI_2016 projections can produce consistent central forecasts, allowing users to place greater reliance on the outputs of the stochastic model.

10.4 Determining the longevity risk premium

10.4.1 As just discussed, the provider of any longevity hedge requires a premium to assume longevity risk. This means that the forward rate agreed at the start of any *q*-forward contract will be below the anticipated (expected) mortality rate on the maturity date of the contract. Similarly, the implied forward life expectancy in any longevity swap will be higher than the anticipated (expected) life expectancy. Figure 14 shows a typical relationship between the expected and forward mortality rate curves and the risk premium for a particular cohort currently aged 65.[68] Figure 15 shows the relationship between the expected and forward mortality rate curves and the risk premium for a particular age (in this case 65-year-old English & Welsh males) for years 2005-25: the further into the future, the more uncertainty there is in the mortality rate and the bigger the risk premium.

Figure 15: Cohort Expected and Forward Mortality Rate Curves
for a Cohort Currently Aged 65 and *q*-Forward Maturity at Age 75

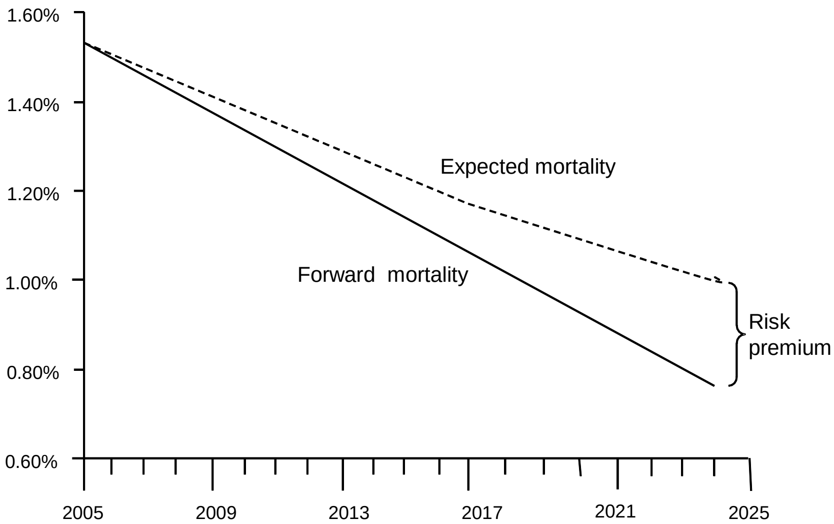
[68] Loeys *et al*. (2007) relate the forward mortality rate to the expected mortality rate through the formula $q^f = (1 - T \times \lambda \times \sigma) q^e$, where q^f is the forward mortality rate, q^e is the expected mortality rate, *T* is the time to maturity, σ is the volatility (annualized standard deviation) of changes in the mortality rate , and λ is the annualized Sharpe ratio required by the counterparty (sometimes also referred to as the market price of risk).



Note: Lines are illustrative only

Source: Adapted from Loeys et al. (2007, Chart 9)

Figure 14: Expected and Forward Mortality Rate Curves
for 65-year-old English & Welsh Males, 2005-25



Note: Lines are illustrative only

Source: Adapted from Coughlan (2007a)

10.4.2 As remarked above, a stochastic model can be used to assess how much uncertainty there is in the underlying hedge instrument, and then use this information to determine an appropriate risk premium. There are different approaches to setting the price, for example: discounting the expected payoff at an appropriate risk-adjusted discount rate that reflects the assessed level of risk; or calculating a risk-adjusted expected payoff prior to discounting at the risk-free rate. When applied to the pricing of multiple contracts, not all frameworks will produce consistent prices over a range of contracts and maturities. However, the method of risk adjustment proposed by Cairns et al. (2006) using an explicit market price of risk for each period effect and for each year is one that does guarantee price consistency. This can be used to determine what might be thought of as mid-market prices, around which participants in the market can set buying and selling prices that reflect the degree of market illiquidity.

10.5 Estimating regulatory capital relief

10.5.1 In Section 7.2 above, we discussed regulatory capital. Under Solvency II, an insurer's regulatory capital can be reduced if its liabilities are appropriately hedged.

10.5.2 This necessitates bringing the relevant regulatory authority on board sooner rather than later, as experience in the Netherlands shows. The Dutch financial regulator, the Dutch National Bank (DNB), assesses longevity hedges on a case-by-case basis. A particular case is insurance, pensions and investments firm Delta Lloyd's two index-based longevity hedges.[69] Delta Lloyd had its Solvency II capital ratio reduced by 14 percentage points at the end of 2015 following 'intense discussions'. This was due to a disagreement with the DNB about the inclusion of risk margin relief on the two longevity hedges beyond the duration of the hedges. The DNB treats an index-based hedge as a financial instrument, whereas it treats a customized hedge as a reinsurance contract. It wanted the index-based hedges to be restructured to 'ensure reinsurance treatment', otherwise Delta Lloyd faced a further 7 percentage points deduction from its Solvency II ratio.

10.5.3 In June 2016, the DNB clarified its position. It agreed that for an index-based swap, capital relief will be proportional to the risk transfer. However, it felt that some previous index-based deals had been of too short duration, too out-of-the-money, and not a good match for actual liabilities.[70]

10.5.4 A detailed account of how to calculate regulatory capital relief in a longevity hedge can be found in Cairns and El Boukfaoui (2017).[71] They describe a flexible framework that blends practical issues with current academic modelling work. Key elements include careful assessment of basis risk, subdivided into population basis risk and other sources. They then consider a specific longevity hedge with a call option spread payoff structure and analyse the impact on regulatory capital. A key conclusion is that the balance between population basis risk and other sources of basis risk (especially structural basis risk) is highly dependent on the exhaustion point of the underlying option. For example, in a Solvency II setting, if the exhaustion point is close to the 99.5% quantile of the underlying risk, the recognition of population basis risk can have a significant effect on the regulatory capital required. In contrast,

[69] See Section 11 below.
[70] See: Pigott and Walker (2016); Solvency II Troubleshoot: Longevity Swaps and Risk Margin Relief, *InsuranceERM*, 17 May 2016; https://www.insuranceerm.com/analysis/solvency-ii-troubleshoot-longevity-swaps-and-risk-margin-relief.html
[71] With or without regulatory capital requirements, their methodology can be applied equally well (and, arguably, more cleanly) to economic capital relief using an insurer's own economic capital framework and risk appetite.

if the exhaustion point is somewhat below the 99.5% quantile (e.g., 95%), then population basis risk has a negligible impact on the amount of regulatory capital relief.[72] In the latter case, therefore, the index-based hedge acts in a very similar way to a reinsurance arrangement with similar attachment and exhaustion points in terms of its impact on regulatory capital. The authors conclude that hedgers need to consider carefully the terms of an index-based hedge (in the case considered, the attachment and exhaustion points, and the maturity date), to ensure the best outcome. Further, in light of the evidence in the previous two paragraphs, insurers should simultaneously discuss their plans with their local regulator before proceeding with a hedge. Bearing this in mind, Cairns and El Boukfaoui (2017) outline a clear set of steps that can be used to document regulatory capital relief calculations with the recommendation that these steps be followed as a way to facilitate discussions with local regulators. This includes a requirement to document clearly the structure of the two-population stochastic mortality model, how this is calibrated, how death rates get extrapolated to high ages, and how central forecasts will be determined at future valuation dates incorporating new information up to that valuation date.

10.6 Comparison of Risk Management Options

Good risk management practice includes consideration of a variety of viable options for reducing exposure to longevity risk, and stochastic models have a key quantitative role, alongside qualitative criteria, in the process that leads to choosing one option over another. Cairns (2014) outlines some of the issues. The stochastic model can be used in a consistent way to evaluate a hedger's longevity risk profile with and without each of the hedging options in place. The range of options itself might be constrained by the size of the liability to be hedged (for example, customised longevity swaps have typically been restricted to larger pension plans) but should, in the first instance, include both customised and index-based hedges. Any analysis should also take into account a hedger's exposure to idiosyncratic risk. Once residual risk has been evaluated, the hedger is then in a position to compare the different options. This should take into account the hedger's general risk appetite as well as the underlying price for a hedge (Section 10.4) and future requirements for adjustments to the hedge (e.g. a buy-in used prior to a full buy-out). Cairns (2014) discusses, in a stylised fashion, how these multiple inputs can result in different final decisions: one size does not fit all.[73]

11. Developments in the Longevity De-risking Market since 2006

11.1 As mentioned at the beginning of this article, the global longevity de-risking market began in the UK in 2006. Prior to this time, the UK market was dominated by two life assurers, Prudential[74] and Legal & General (L&G), which did business of approximately £2bn a year across a large number of small transactions. The total potential size of the UK market alone is around £2.7trn and this encouraged a raft of new players, in particular mono-line insurers, to

[72] For the examples in Cairns and El Boukfaoui (2017) if the exhaustion point is at the 99.5% quantile the inclusion of population basis risk can reduce regulatory capital relief by around 15% to 20%, In contrast, if the exhaustion point is at the 95% quantile, the impact on regulatory capital relief of population basis risk is effectively zero.

[73] For example, a highly risk averse hedger will normally opt for a customised hedge, whereas a hedger with a greater appetite for risk might favour an index-based hedge if the price is right.

[74] We will use Prudential to refer to the UK-based insurer.

enter the market.[75] The first of these was Paternoster, but others quickly followed including Pension Insurance Corporation (PIC), Synesis[76] and Lucida,[77] all of which were backed by investment banks and private equity investors. In 2007, Goldman Sachs established its own pension insurer, Rothesay Life. Paternoster[78] executed the first buy-out in November 2006 of the Cuthbert Heath Family Plan, a small UK plan with just 33 members. It also executed the first pensioner buy-in with Hunting PLC in January 2007.[79]

11.2 The world's first publicly announced longevity swap between Swiss Re and the UK life office Friends' Provident in April 2007 (although this was structured as an insurance or indemnification contract rather than a capital market transaction). 2007 also saw the release of the LifeMetrics Indices covering England & Wales, the US, Holland and Germany by J.P. Morgan, the Pensions Institute and Willis Towers Watson (WTW) (then Towers Watson).[80] Xpect Age and Cohort Indices were launched in March 2008 by Deutsche Börse.[81] These indices cover, respectively, life expectancy at different ages and survival rates for given cohorts of lives in England & Wales, the US, Holland, and Germany and its regions. The purpose of these indices is to provide a benchmark for the trading of longevity-linked instruments. In 2009, longevity swaps began to be offered to the market based on Deutsche Börse's Xpect Cohort Indices.

11.3 The world's first capital market derivative transaction, a *q*-forward (or mortality forward) contract,[82] between J. P. Morgan and the UK pension fund buy-out company Lucida, took place in January 2008. The world's first capital market longevity swap was executed in July 2008: Canada Life hedged £500m of its UK-based annuity book (purchased from the defunct UK life insurer Equitable Life). This was a 40-year swap customized to the insurer's longevity exposure to 125,000 annuitants. The longevity risk was fully transferred to investors, which included hedge funds and ILS funds. J. P. Morgan acted as the intermediary and assumes counter-party credit risk. In August 2011, ITV, the UK's largest commercial TV producer, completed a £1.7bn bespoke longevity swap with Credit Suisse for its £2.2bn pension plan: the cost of the swap is reported as £50m (3% of the notional swap value).[83] In February 2010, Mercer launched a pension buy-out index for the UK to track the cost charged by insurance companies to buy out corporate pension liabilities: at the time of launch, the cost was some 44% higher than the accounting value of the liabilities which highlighted the attraction of using cheaper alternatives, such as longevity swaps.[84]

11.4 On 1 February 2010, the Life and Longevity Markets Association (LLMA) was established in London. Its current members are Aviva, AXA, Deutsche Bank, J.P. Morgan,

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[75] The timing was motivated by a number of external factors, such as a strengthened funding standard, increased accounting transparency of pension liabilities on corporate balance sheets, the establishment of the PPF with risk-based levies that depended on the size of plan deficits, and the beginning of the closure of defined benefit pension plans.
[76] Acquired by PIC in 2008.
[77] Acquired by L&G in 2013.
[78] Acquired by Rothesay Life in 2011.
[79] See Appendix A for a full list of publicly announced UK buy-ins between 2007 and 2016.
[80] Coughlan et al. (2007).
[81] www.deutsche-boerse.com/xpect_e
[82] Coughlan et al. (2007b).
[83] https://www.professionalpensions.com/professional-pensions/news/2104113/gbp17bn-itv-deal-predicted-spark-longevity-swaps-surge
[84] https://www.uk.mercer.com/newsroom/global-buyout-index.html

Morgan Stanley, Prudential, and Swiss Re**.** LLMA was formed to promote the development of a liquid market in longevity- and mortality-related risks.

11.5 This market is related to the ILS market and is also similar to other markets with trend risks, e.g., the market in inflation-linked securities and derivatives. LLMA aims to support the development of consistent standards, methodologies and benchmarks to help build a liquid trading market needed to support the future demand for longevity protection by insurers and pension funds. In April 2011, the LifeMetrics indices were transferred to LLMA with the aim of establishing a global benchmark for trading longevity and mortality risk.

11.6 In December 2010, building on its successful mortality catastrophe Vita bonds and taking into account the lessons learned from the failed EIB/BNP longevity bond, Swiss Re launched an eight-year longevity-spread bond valued at \$50m. To do this, it used a special purpose vehicle, Kortis Capital, based in the Cayman Islands. As with the mortality bonds, the longevity-spread bonds are designed to hedge Swiss Re's own exposure to mortality and longevity risk. In particular, holders of the bonds face a reduction in principal if there is an increase in the spread between mortality improvements in 75-85-year-old English & Welsh males and 55-65-year-old US males, indicating that Swiss Re has life insurance (mortality risk) exposure in the US and pension (longevity risk) exposure in the UK.[85]

11.7 The world's first longevity swap for non-pensioners (i.e., for active and deferred members of a pension plan) took place in January 2011, when J. P. Morgan executed a £70m 10-year *q*-forward contract with the Pall (UK) pension fund. This was a value swap designed to hedge the longevity risk in the value of Pall's pension liabilities, rather than the longevity risk in its pension payments as in the case of cash flow swaps – which have been the majority of the swaps that have so far taken place. Longevity risk prior to retirement is all valuation risk: there is no cash flow risk and most of the risk lies in the forecasts of mortality improvements at specific future valuation dates. Further, the longevity exposure of deferreds is not well defined as a result of the options that plan members have, e.g., lump sum commutation options, early retirement options, and the options to increase spouses' benefits at the expense of members' benefits.

11.8 In 2011, WTW introduced the pension captive structure. A plan executes a pensioner buy-in with a standard insurer[86], but then the insurer reinsures the buy-in with a captive insurer owned by the sponsor. Captives can provide a cost-effective solution compared with either a traditional buy-in or directly running the plan over the longer term. This is because there can be a more efficient blending of investment management services with insurance, combined with a more effective disaggregation of risks and hence a more capital-efficient management of those risks. The first plan to use this structure was Coca Cola in 2011 (Willis Towers Watson, 2017).

11.9 In December 2011, Long Acre Life entered the market to offer cheaper pension insurance solutions to larger plans with liabilities above £500m. Under these solutions companies offload their pension plans to an insurance vehicle in which they also invest and so share the profits along with external investors: the target return is 15% p.a.[87] In January 2012, L&G began

[85] The Kortis bond is analyzed in Hunt and Blake (2015).
[86] The standard insurer needs to be UK regulated, the captive is off-shore; the standard insurer will have the modelling skills etc, while the captive is effectively an empty shell.
[87] This proposition failed to attract sufficient commercial interest and the company was dissolved in January 2016.

offering longevity insurance (in the form of deferred buy-ins) for the 1,000 or so smaller plans with liabilities in the range £50-£250m. In February 2012, UK pension consultant Punter Southall adopted PensionsFirst's pension liability and risk management software (PFaroe) to automate the production of actuarial valuations and hence cut costs for pension plans, particularly small ones. In the same month, another UK consultant Hymans Robertson, launched a pension de-risking monitoring service which compares the costs of a full buy-out with the costs of a buy-in covering only pensioner members and the costs of a longevity swap.

11.10 The first pension risk transfers deals outside the UK took place in 2009-11. The first buy-in deal outside the UK was in 2009 in Canada; it was arranged by Sun Life Financial and valued at C$50m. The first buy-in deal in Europe was in December 2010 between the Dutch food manufacturer Hero and the Dutch insurer Aegon (€44m). The first buy-in deal in the US took place in May 2011 between Hickory Springs Manufacturing Company and the Prudential Insurance Co of America (PICA)[88] ($75m). The first buy-out deal outside the UK was announced in May 2011 and involved the C$2.5bn Nortel pension plan in Canada. In September 2011, CAMRADATA Analytical Services launched a new pension risk transfer (PRT) database for US pension plans. The database provides insurance company organisational information, pension buy-in and buy-out product fact sheets and screening tools, pricing data, up-to-date information on each PRT provider's financial strength and relevant industry research. Users can request pension buy-in and buy-out quotes directly from providers, including American General Life Companies, MetLife, Pacific Life, Principal Financial Group, PICA, Transamerica and United of Omaha.

11.11 The first international longevity reinsurance transaction took place in June 2011 between Rothesay Life (UK) and PICA (US) and was valued at £100m. The first life book reinsurance swap since the Global Financial Crisis (GFC) of 2007-08 also took place in June 2011 between Atlanticlux and institutional investors and was valued at €60m.

11.12 In February 2012, Deutsche Bank (through its insurance subsidiary Abbey Life) executed a huge €12bn index-based longevity swap for insurer Aegon in the Netherlands. This solution was based on Dutch national population data and enabled Aegon to hedge the liabilities associated with a portion of its annuity book (of €30bn). Deutsche Bank pays floating payments associated with the realized mortality rates of the reference index, but these payments are capped and floored. Aegon pays fixed premiums. The maturity of the swap is 20 years. A commutation mechanism determines the payment at maturity – the mechanism is designed to provide longevity protection for liability cashflows occurring beyond the 20-year maturity point. The swap has the structure of a series of call option spreads each with a long out-of-the money call at a strike price (or floor) and a short out-of-the money call at a higher strike price (or cap). Because the swap began deep out of the money (i.e., the floor is considerably higher than initial mortality rates), the amount of longevity risk actually transferred is far less than that suggested by the €12bn notional amount. Nonetheless, the key driver for this transaction from Aegon's point of view was the reduction in regulatory capital it achieved. Most of the longevity risk has been passed to investors in the form of private bonds and swaps.[89]

[88] We will use PICA to refer to the US-based insurer or its subsidiaries such as Prudential Financial or Prudential Retirement.

[89] https://www.cass.city.ac.uk/__data/assets/pdf_file/0008/141587/Sagoo_Douglas_presentation.pdf

11.13 In June 2012, General Motors Co. (GM) announced a massive deal to transfer up to $26bn of pension obligations to PICA. This is by far the largest ever longevity risk transfer deal globally. The transaction is effectively a partial pension buy-out involving the purchase of a group annuity contract for GM's salaried retirees who retired before 1 December 2011 and refused a lump sum offer in 2012. To the extent retirees accepted a lump sum payment in lieu of future pension payments, the longevity risk was transferred directly to the retiree.[90] The deal was classified as a partial buy-out rather than a buy-in because it involved the settlement of the obligation. In other words, the portion of the liabilities associated with the annuity contract will no longer be GM's obligation. Moreover, in contrast to a buy-in, the annuity contract will not be an asset of the pension plan, but instead an asset of the retirees. In October 2012, GM did a $3.6bn buy-out of the pension obligations of its white-collar retirees. Also in October 2012, Verizon Communications executed a $7.5bn bulk annuity buy-in with PICA. The buy-out deals in the U.S. in 2012 amounted to $36bn.

11.14 The buy-outs for private sector pension plans had all involved plans that were closed to future accrual. However, in March 2012, PIC executed the first buy-out of a plan open to future accrual: the sponsoring employer, the high-tech manufacturer Denso, will pay PIC an annual premium based on the number of active members and their salaries, but PIC will assume all the liabilities. PIC had previously conducted an innovative buy-in in May 2011 with the London Stock Exchange's defined benefit pension plan which not only insured current pensioner members, but will also automatically insure active and deferred members when they reach retirement.

11.15 In June 2012, the OECD released the first edition of *Pensions Outlook*. This called on governments to kick-start the creation of a functioning longevity risk market and consider issuing longevity bonds, without which the annuity market is unlikely to work well. In September 2012, Swiss Re Europe released a report entitled *A mature market: Building a capital market for longevity risk.* The report called for the development of a capital market for longevity risk. It said that 'Society's longevity risk could be tackled to a greater extent if reinsurers were able to expand their capacity, and this could be done by encouraging capital market investors to invest in longevity instruments. …The main challenges include achieving transparency in measuring the risk and potential liability, building a secondary market, increasing investor education, providing the right level of return and regulation'.[91]

11.16 In December 2012, the enhanced buy-in market opened for business in the UK for defined benefit pension plans. An enhanced buy-in is where a plan's trustees buy a group annuity as an investment of the plan, where some or all of the members covered by the policy are medically underwritten. Medical underwriting, which is now commonplace in the individual annuity market (i.e., in relation to defined contribution pensions), has the potential to reduce the cost to the plan of the longevity hedge compared with standard annuities, on the grounds that certain members might have lower than average life expectancy as a result of their lifestyle or some serious life-shortening illness. The market was introduced by two specialist insurers, Partnership and Just Retirement, but other larger insurers followed, e.g., L&G which offers a Large Individual Defined Benefit Annuity (LIBDA) service.

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[90] In fact, the lump sum is only being offered to limited cohorts of plan members.

[91] http://www.swissre.com/media/news_releases/nr_20120924_capital_market_longevity.html

11.17 In February 2013, the first medically underwritten bulk annuity (MUBA) transaction was executed in the UK by Partnership (Harrison and Blake, 2013). This involved each member filling in a medical questionnaire in order to get a more accurate assessment of their life expectancy based on their medical history or lifestyle. This was particularly useful in the case of 'top slicing', where plan trustees insure the pensioners (who will typically be the company directors) with the largest liabilities and who therefore represent a disproportionate risk concentration for the plan. In December 2014, Partnership executed a £206m medically underwritten bulk annuity transaction with a top slicing arrangement for the £2bn Taylor Wimpey pension plan. L&G transacted a £230m medically-underwritten buy-in in December 2015 with the Kingfisher Pension Scheme, covering 149 high-value members. The process of collecting medical information has been streamlined in recent years using third-party medical data collectors, such as MorganAsh, Age Partnership and Aon's AHEAD platform – all of which perform MUMS (medically underwritten mortality studies). It is expected that the share of medically underwritten de-risking deals will increase significantly over the next few years in the UK, with new business more than doubling from £540m in 2014 to £1,200m in 2015, i.e., from 5% to 12.5% of the market (Hunt and Blake, 2016). In April 2016, the two largest UK medical underwriters, Partnership and Just Retirement – which both entered the market in 2012 – merged to form Just valued at £16bn. In December 2016, Just executed a £110m medically underwritten buy-in with the Land Securities Group of Companies' defined benefit pension fund.

11.18 In April 2013, L&G reported its first non-UK deal, the buy-out of a €136m annuity book from New Ireland Life. In June 2013, the Canadian Wheat Board executed a C$150m pension buy-in from Sun Life of Canada, involving inflation-linked annuities, while in March 2014, an unnamed Canadian company purchased C$500m of annuities from an insurer reported to be Industrial Alliance, making it the largest ever Canadian pension risk transfer deal to date.

11.19 In August 2013, Numerix, a risk management and derivatives valuation company, introduced a new asset class called 'life' on its risk modelling platform (in addition to equities, bonds and commodities).

11.20 In September 2013, UK consultant Barnett Waddingham launched an insurer financial strength review service which provides information on an insurer's structure, solvency position, credit rating, and key risks in their business model. This service was introduced in response to concerns about the financial strength of some buy-out insurers.

11.21 In November 2013, SPX Corp. of Charlotte, NC, purchased a buy-out contract with Massachusetts Mutual Life Insurance Co. as part of a deal that moved $800m in pension obligations off SPX's balance sheet.

11.22 Also in November 2013, Deutsche Bank introduced the Longevity Experience Option (LEO). It is structured as an out-of-the-money bull call option spread on 10-year forward survival rates and has a 10-year maturity. The survival rates are based on males and females in five-year age cohorts (between 50 to 79) derived from the England & Wales and Netherlands LLMA longevity indices. LEOs are traded over-the-counter under a standard ISDA[92] contract. They allow longevity risk to be transferred between pension funds, insurance companies and investors. They are intended to provide a cheaper and more liquid alternative to bespoke longevity swaps which are generally costly and time consuming to implement. Purchasers of

[92] International Swaps and Derivatives Association.

the option spread, such as a pension fund, will gain if realized survival rates are higher than the forward rates, but the gains will be limited, thereby providing some comfort to the investors providing the longevity hedge. The 10-year maturity is the maximum that Deutsche Bank believes investors will tolerate in the current stage in the development of a market in longevity risk transfers. It was reported that Deutsche Bank executed its first LEO transaction with an ILS fund in January 2014.[93]

11.23 In December 2013, Aegon executed a second longevity risk transfer to capital markets investors and reinsurers, including SCOR. Société Générale was the intermediary in the deal covering liabilities of €1.4bn and RMS was the modelling agent. The main difference with the Deutsche Bank hedge is that there is a single payment by Société Générale to Aegon if the swap is in-the-money at maturity.

11.24 Also in December 2013, the Joint Forum reported on the results of its consultation on the longevity risk transfer market. It concluded that this market is not yet big enough to raise systemic concerns, but 'their massive potential size and growing interest from investment banks to mobilize this risk make it important to ensure that these markets are safe, both on a prudential and systemic level' (Joint Forum, 2013, p.2).

11.25 In February 2014, the Mercer Global Pension Buy-out Index was introduced. It shows the benchmark prices of 18 independent third-party insurers in four countries with significant interest in buying out defined benefit liabilities: UK, US, Canada and Ireland. Costs were highest in the UK where the cost of insuring £100m of pension liabilities was 123% of the accounting value of the liabilities[94] – equivalent to a price of £32 per £1 p.a. of pension (Towers Watson, 2015). The comparable costs in Ireland, the US and Canada were 117%, 108.5% and 105%, respectively. The higher cost in the UK is in part due to the greater degree of inflation uprating of pensions in payment in the UK compared with the other countries. The difference between the US and Canada is explained by the use of different mortality tables. Rising interest rates (following the unwinding of global quantitative easing programmes) and equity markets will lower funding deficits and hence lead to lower buy-out costs in future, especially in the US.

11.26 In July 2014, Mercer and Zurich launched Streamlined Longevity Solution, a longevity swap hedge for smaller pension plans with liabilities above £50m. This is part of a new Mercer SmartDB service which provides bespoke longevity de-risking solutions and involves a panel of reinsurers led by Zurich. It reduces the costs by having standardized processes for quantifying the longevity risk in each pension plan. The first deal, valued at £90m, was transacted with an unnamed UK pension plan in December 2015. A second deal – this time with the UK pension plan of the Italian tyre company Pirelli – was executed in August 2016 for £600m.

11.27 In December 2014, WTW launched Longevity Direct, an off-shore longevity swap hedging service that gives medium-sized pension plans with liabilities between £1-3bn direct

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93 https://www.professionalpensions.com/professional-pensions/news/2305081/deutsche-bank-launches-longevity-swap-alternative; http://www.artemis.bm/blog/2013/11/04/first-longevity-experience-option-to-be-traded-by-deutsche-bank-by-year-end/

94 Note from paragraph 11.3 above that the UK buy-out premium was 44% in February 2010, indicating how volatile the premium can be and the importance of getting the timing of the buy-out right to minimize costs.

access to the reinsurance market, via its own cell (or captive) insurance company. This allows plans to bypass (or pass through) insurers and investment banks – the traditional de-risking intermediaries – and significantly reduces transactions costs and completion times, while still getting the best possible reinsurance pricing. The first reported transaction on the Longevity Direct platform was the £1.5bn longevity swap executed by the Merchant Navy Officers Pension Fund (MNOPF) in January 2015 which was insured by MNOPF IC, a newly established cell insurance company based in Guernsey, and then reinsured with Pacific Life Re. In February 2015, PwC launched a similar off-shore longevity swap service for pension plans as small as £250m. It uses a Guernsey-based incorporated cell company called Iccaria, established by Artex Risk Solutions, to pass longevity risk directly on to reinsurers. The arrangement is fully collateralized and each plan owns a cell within Iccaria which again avoids the costs of dealing with insurer and investment bank intermediaries. WTW also introduced the first tracking software system to follow live insurer pricing, sending alerts when a plan closes in on a target price.

11.28 There is evidence of increasing demand from reinsurance companies for exposure to large books of pension annuity business to offset the risk in their books of life insurance.[95] For example, in July 2014, Warren Buffett's Berkshire Hathaway agreed to a £780m quota-reinsurance deal with PIC. Similarly, in August 2014, Delta Lloyd executed a 6-year index-based longevity swap covering €12 billion of its longevity reserves with Reinsurance Group of America (RGA Re),[96] while AXA France executed a €750m longevity swap with Hannover Re.

11.29 In March 2014, L&G announced the biggest single buy-out in the UK to date when it took on £3bn of assets and liabilities from ICI's pension plan, a subsidiary of AkzoNobel. The deal uses 'umbrella' contracts which enables the plan to add further liabilities onto the original contract.[97] In December 2014, L&G announced the largest ever UK buy-in valued at £2.5bn with US manufacturer TRW. In fact, in 2014, TRW became the first global corporation to simultaneously complete three de-risking transactions in three different countries: the UK, the US and Canada. Also in 2014, the Aviva Staff Pension Scheme completed the first limited recourse longevity swap, involving £5 billion in liabilities and 19,000 participants.

11.30 Around £13bn of bulk annuity deals were executed in the UK in 2014, the largest volume of business since the de-risking market began in 2006 and beating the previous best year of 2008, just before the Global Financial Crisis, when £7.9bn of deals were completed. The total volume of de-risking deals in the UK in 2014 alone (covering buy-outs, buy-ins and longevity swaps) was £35bn. Included in this sum is the UK's largest transaction to date, namely the longevity swap for the British Telecom (BT) Pension Scheme, covering £16bn of pension liabilities, arranged by PICA in July 2014. To complete the transaction, the BT scheme created its own captive insurer located in Guernsey, which insured the longevity risk. The

[95] The biggest buyers of longevity risk at the present time are global reinsurers. Nevertheless, according to Hannover Re: 'The number of risk-takers is limited and there is no unlimited capacity in the market for taking on longevity risk. The increasing worldwide demand for longevity cover will challenge the capacity for securing longevity risk' (quoted in Punter Southall (2015)).

[96] http://www.artemis.bm/blog/2014/08/22/delta-lloyd-in-eur-12-billion-index-based-longevity-swap-with-rga-re/

[97] By October 2016, the ICI plan had completed 11 such deals – with L&G, Prudential (UK) and Scottish Widows – with a total value of £8bn, saving the parent company over £100m in costs.

captive insurer then reinsured the risk in a fully collateralized arrangement with PICA. Captive and limited recourse transactions have dominated the market since 2014.

11.31 In response to the announcement by the UK finance minister (George Osborne) in his Budget Speech on 19 April 2014, that UK pension plan members no longer needed to buy annuities when they retired (which resulted in an immediate fall in annuity sales of more than 50%), a number of traditional annuity providers, such as Scottish Widows, reported that they were considering entering the bulk annuity market.

11.32 In November 2014, the Longevity Basis Risk Working Group (2014) of the Institute & Faculty of Actuaries (IFoA) and LLMA published *Longevity Basis Risk: A Methodology for Assessing Basis Risk*.[98] This study develops a new framework for insurers and pension plans to assess longevity basis risk. This, in turn, will enable simpler, more standardized and easier to execute index-based longevity swaps to be implemented. Index-based longevity swaps allow insurers and pension plans to offset the systemic risk of increased liabilities resulting from members living longer than expected. It had hitherto been difficult to assess how effectively an index-based longevity swap could reduce the longevity risk in a particular insurance book or pension plan. The methodology they developed is applicable to both large plans (which are able to use their own mortality data in their models) and smaller plans (by capturing demographic differences such as socio-economic class and deprivation). In May 2016, a follow-up study – to be carried out by Macquarie University, Mercer Australia, and the University of Waterloo – was announced. The purpose was to design a 'readily applicable methodology' for use with longevity risk indices: 'Such indices are often used in pension benefits and annuitant liabilities, as well as in providing actuaries with key data, …but the problem of the existence of basis risk remains unsolved'. This follow-up study was published in December 2017 (Li et al., 2017). The report distinguishes between three types of basis risk (population, sampling and structural basis risk) and takes the proposed models in the 2014 report through to full analysis of hedge effectiveness. The report contains extensive numerical analyses that consider how hedge effectiveness depends on a range of input variables, including different book populations, size of book population, and type of hedge instrument, as well as the sensitivity to the underlying risk measure itself.

11.33 In March 2015, the UK government announced that it would introduce a new competitive corporate tax structure to allow ILSs to be domiciled in the UK. In May 2015, Rothesay Life, the insurance company owned by Goldman Sachs, bought out the liabilities of Lehman Brothers' UK pension plan for £675m, thereby securing the pensions of former employees of the company associated with the beginning of the Global Financial Crisis. In April 2016, Rothesay Life bought two-thirds of Aegon's UK annuity book – representing 187,000 policy holders – for £6bn, bringing total assets under management to £20bn and total lives assured to over 400,000. This was the first substantial annuity transfer since the introduction of Solvency II in January 2016. Solvency II has increased capital requirements and has reduced the attractiveness of annuities as a business line for certain insurers and raised buy-out prices by 5-7%.[99] Deferred members are the most expensive to insure, since their life expectancy is the most uncertain, given their younger ages – yet they comprise 45% of the membership of UK plans (i.e., 4.9m members).[100]

[98] A version of this report was subsequently published as Villegas et al. (2017).
[99] *Financial News*, 28 March–3 April 2016.
[100] The Pension Regulator and the Pension Protection Fund, *Purple Book 2015*.

11.34 In April 2015, Swiss Re Capital Markets led the issuance of €285m of excess mortality insurance-linked securities by Benu Capital Limited (Benu) on behalf of AXA Global Life. Swiss Re Capital Markets underwrote the transaction via two classes of principal-at-risk variable rate notes issued by Benu, an Irish private company incorporated with limited liability. The notes have a five-year risk period starting on 1 January 2015. The proceeds of the notes each collateralize a counterparty contract with AXA Global Life, providing protection against excess mortality in France, Japan and the US via country age and gender weighted population mortality indices. It was the largest excess mortality issuance since 2007.[101]

11.35 The largest buy-out to date in the UK was for the Philips Pension Fund which in November 2015 completed a full buy-out of the pension benefits of 26,000 members valued at £2.4bn with PIC. An interesting feature of this deal was that a buy-out was combined with a longevity hedge. The longevity risk was simultaneously reinsured with Hannover Re. Another interesting feature was that it covered both retired and deferred members, with the latter's benefits valued at £1bn.

11.36 An important new longevity-linked product that took off in the UK in 2015 was the equity release mortgage. This allows individuals to release equity in their homes to fund their retirement without downsizing. L&G, for example, set up L&G Home Finance for this purpose and in its first year completed more than £400m equity release mortgage sales. Since equity release contracts typically involve a no negative equity guarantee,[102] the product provider is exposed to the risk that mortgagors live longer than expected.

11.37 In 2015, L&G directly entered both the US and European pension risk transfer markets. It executed a $450m transaction with the US subsidiary of Royal Philips covering 7,000 plan members in October and a €200m deal with ASR Nederland NV, a Dutch insurer in December. The pension obligations were transferred to L&G Re in cooperation with Hannover Re. L&G said: 'The pension risk transfer market has become a global business…The potential market for pension risk transfer in the US, UK and Europe is huge, and will play out over many decades'. Two US insurers were also involved in the Royal Philips deal: PICA acquired $450m of plan liabilities covering another 7,000 members, while American United Life Insurance Company issued annuity contracts to 3,000 deferred plan members, valued at $200m.

11.38 In January 2015, the Bell Canada Pension Plan executed a C$5bn longevity swap with Sun Life Financial,[103] SCOR, and RGA Re; it was SCOR's first transaction in North America. In the process, Canada became the first country apart from the UK to have all three pension risk transfer solutions actively in use. In the same year, it completed its first inflation-linked buy-in annuity transaction, while in 2017 it completed its first buy-in annuity covering active future benefits.[104] In June 2015, Delta Lloyd did a second €12bn longevity swap with RGA Re:

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101 http://www.swissre.com/media/news_releases/nr_20150428_large_excess_mortality_issuance.html

102 That is, the amount that the individual or their estate (if the individual dies) needs to repay (i.e., amount borrowed plus accrued interest) cannot exceed the equity in the home.

103 Sun Life Financial uses the RMS Longevity Risk Model, which RMS describes as a 'structural meta-model of geroscience advancement'.

104 Eckler Consultants (2017) *Pension Risk Transfer Report*, November.

the swap was also index-based, with an 8-year duration and had a notional value of €350m.[105] In July 2015, Aegon did one valued at €6bn with Canada Life Re, a new entrant to the de-risking market in 2015. Another new entrant was Scottish Widows.

11.39 In June 2015, the Mercer Pension Risk Exchange was launched. It gives clients in the US, UK and Canada up to date buy-in and buy-out pricing based on their plan's data. It collects prices provided monthly by insurers in the bulk market, based on plan benefit structures and member data. Mercer said: 'Many companies have the appetite to transfer pension risk off their balance sheet but they face barriers: lack of clear information about the true cost of a buy-in or buy-out, limited transparency, the fluctuation of market rates and plan economics to name but a few. [The exchange will enable] sponsoring employers and trustees to be more strategic and sophisticated in their approach and to know that they are executing a buy-in or a buy-out at the best time for them and at a competitive price'.

11.40 In April 2016, WTW released PulseModel which uses medical science and the opinions of medical experts to improve longevity predictions. For example, the model predicts that 16% of 50-year-old men in the UK will develop type-2 diabetes in the next 20 years, but this rises to 50% for those who are both obese and heavy smokers. Overall, the model predicts that longevity improvements in the future will be lower than currently predicted, at around 1% p.a. rather than 1.5%. If this turned out to be correct, then the current price of longevity of risk transfer products would be too high.

11.41 In 2016, there were a total of £8.6bn in buy-outs and buy-ins and £1.6bn in longevity swaps.[106]

11.42 The largest buy-in in 2016 (in December) was Phoenix Life's £1.2bn buy-in for the 4,400 pensioners in the PGL Pension Scheme, which is sponsored by the Phoenix Group, Phoenix Life's parent company. This replaced a longevity swap it had set up for the plan in 2014. This is the first example a transaction which transforms a longevity swap into a bulk annuity. Phoenix Life saw this as an opportunity to bring £1.2bn of liquid assets (mostly UK government bonds) onto its balance sheet, which could then be swapped into a higher yielding, matching portfolio, structured to maximize the capital benefit under Solvency II. This, in turn, meant that Phoenix Life would be assuming the market risks associated with the PGL Scheme pension liabilities in addition to the longevity risks – and already does this on its existing book of individual annuities which are backed by £12bn of assets. The timing was also critical. Phoenix wanted to ensure that its internal model under Solvency II had bedded down well and that the capital and balance sheet impacts of the transaction were well understood, and that Phoenix had elicited the full support of the PRA for the transaction, thereby ensuring execution certainty. Phoenix also provided comfort to the plan's trustees by giving them 'all-risks' cover from point of buy-in ('all-risks' cover is not usually provided until buy-out) and strong collateral protection.[107]

11.43 2016 saw the beginning of a trend towards consolidation amongst insurance companies involved in the longevity risk transfer business in the UK. For example, Aegon sold its £9bn

[105] http://www.artemis.bm/blog/2015/06/26/delta-lloyd-rga-in-second-e12-billion-longevity-swap-deal/
[106] Pensionfundsonline, 15 December 2016.
[107] Stephanie Baxter (2017) How PGL's longevity swap was converted into a buy-in, *Professional Pensions*, 10 April.

UK annuity portfolio to Rothesay Life[108] and L&G between April and May, as part of a strategy to free up capital from non-core businesses. Part of the reason for this is the additional capital requirements under Solvency II which only the most efficient firms have the ability to absorb. Similarly, in September, Deutsche Bank sold its Abbey Life subsidiary to Phoenix Life – a consolidator of closed insurance books – for £935mn, as part of a planned programme of disposals aimed at restoring its capital base. There is an estimated £100bn of UK individual annuities in back books and further consolidation of these back books is anticipated. In December 2017, L&G sold its £33bn closed book of traditional insurance-based pensions, savings and investment policies to the ReAssure division of Swiss Re for £650m.

11.44 Solvency II has also been blamed for some companies pulling out of the bulk annuities market altogether, a key example being Prudential in January 2016. Prudential is reported to be selling its £45bn UK annuity and pension liability businesses due to an inadequate return on capital and transfer that capital to its growing businesses in Asia.[109] Reinsurance deals have also increased in response to Solvency II, involving less heavily regulated non-EU reinsurers. For example, PIC executed a £1.6bn longevity reinsurance agreement with PICA in June 2016.

11.45 2016 also witnessed the increasing streamlining and standardization of contracts. This is particularly beneficial to small plans below £100m. Previously, smaller plans have been less attractive to insurers due to the higher costs of arranging such deals relative to the profit earned. To circumvent this, consultants have begun offering services that allow smaller plans to access improved pricing and better commercial terms using a standardized off-the-shelf process incorporating pre-negotiated legal contracts. Pricing is more competitive because the insurer's costs are kept low. An example is WTW's Streamlined Bulk Annuity Service. The increasing maturity of the market has meant that some larger plans have also been prepared to use pre-negotiated contracts (Willis Towers Watson, 2017).

11.46 2016 was also the tenth anniversary of the longevity transfer market. Since its beginning in the UK in 2006, £40bn of buy-outs and £31bn of buy-ins have taken place in the UK, covering 1 million people.[110] Yet this equates to just 5% of the £1.5trn of UK defined benefit (DB) pension assets and 3% of the £2.7trn of DB pension liabilities on a buy-out basis. In addition, forty eight longevity swaps are known to have been completed in the United Kingdom between 2007 and 2016, valued at £75bn and covering 13 insurance companies' annuity and buy-out books, 22 private sector pension funds, and one local authority pension fund (some of which executed more than one swap).[111] Figure 16 shows the growth of the global market in longevity risk transfer between 2007 and 2016. A total of $280bn in transactions have been completed during this period.

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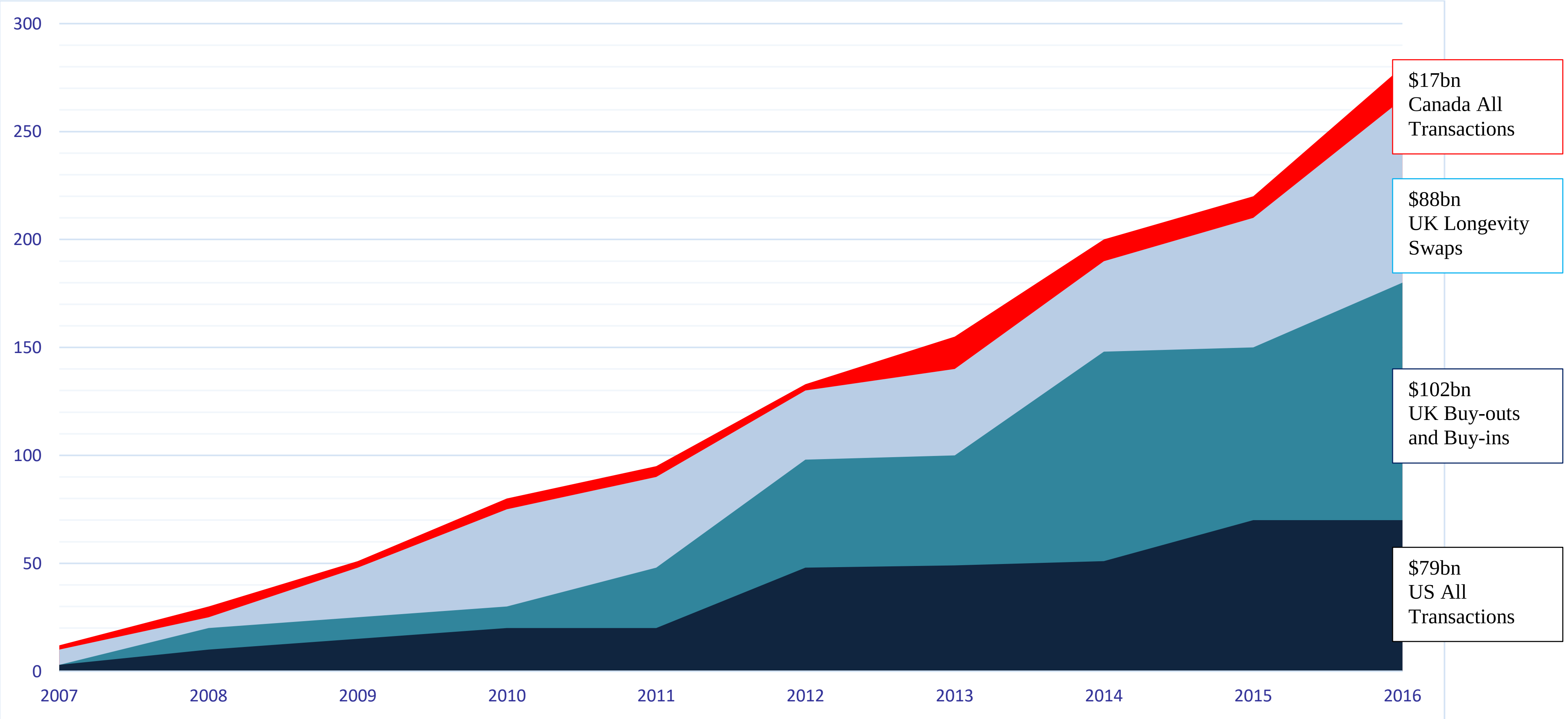
[108] In August 2017, Goldman Sachs sold its remaining stake in Rothesay Life to a consortium comprising US buy-out firm Blackstone, Singapore's sovereign wealth fund GIC, and US life insurer MassMutual in a deal valuing Rothesay Life at around £2bn; http://www.cityam.com/269996/goldman-sachs-sells-final-stake-2bn-rothesay-life

[109] https://www.ftadviser.com/pensions/2016/12/05/prudential-seeks-buyers-for-45bn-annuity-business/

[110] LCP, *Professional Pensions* (15 December 2016 and 26 January 2017). Since 2007, some 92 buy-ins have been completed – see Table A1.

[111] www.artemis.bm/library/longevity_swaps_risk_transfers.html; see Table A2 for a full list of UK publicly announced longevity swaps between 2007 and 2016.

Figure 16: Cumulative Pension Risk Transfers by Product and Country, 2007-16



Sources: LCP, Hymans Robertson, Prudential Financial, Daniel Ben-Ami (2016) Preparing for a jump in longevity, *Pensions & Investments Europe*, December.

11.47 At the beginning of 2017, there were eight UK-domiciled insurers actively participating in the pension risk transfer market in the UK. The largest players are PIC and Legal & General, with market shares of 37% and 30%, respectively. The others are Rothesay Life, Canada Life, Zurich, Scottish Widows, Standard Life, and new entrant Phoenix (since August). Occasionally, the insurers co-operate in a transaction. To illustrate, in August 2017, L&G executed a longevity swap in respect of £800m of the pension liabilities of Scottish and Southern Energy (SSE), while PIC completed a £350m buy-in for the company. According to consultant LCP: '2017 is well on track to exceed £10bn of buy-ins and buy-outs for the fourth year running and has the potential to exceed the record £13.2bn set in 2014. There remains significant capacity and competition – even if a large back-book comes to market – providing attractive opportunities for pension plans to transfer longevity risk through a buy-in or buy-out'.[112]

11.48 One of the largest deals in 2017 (September) involved a £3.4bn longevity swap between the Marsh & McLennan Companies (MMC) UK Pension Fund and both Canada Life Reinsurance and PICA, using Guernsey-based incorporated cell companies, Fission Alpha IC Limited and Fission Beta IC Limited. MMC subsidiary Mercer led the transaction as advisor to the pension fund trustee and the deal was the first to be completed using the Mercer Marsh longevity captive solution, with no upfront premium. The two reinsurers shared the risk equally and the use of the captive ICC vehicle meant that no insurer intermediary was required, making the deal more cost-effective for the pension fund.[113] Also in September, the British Airways' Airways Pension Scheme used a similar Guernsey-based captive insurer to set up a £1.6bn longevity swap. The longevity risk was then reinsured with Partner Re and Canada Life Re. The scheme had previously hedged £2.6bn of liabilities through two longevity swap transactions executed by Rothesay Life in 2010 and 2011.[114] In November 2017, PIC executed a £900m longevity swap with PICA.[115]

11.49 In December 2017, NN Life, part of the Nationale-Nederlanden Group, executed an index-based longevity hedge with reinsurer Hannover Re, in a deal covering the insurer against the longevity trend risk in €3bn of its liabilities. The structure is similar to the 2013 Aegon tail-risk deal arranged by Société Générale. While the term of the transaction is 20 years, NN Life is protected over a longer time period via a commutation function[116] that applies at maturity. If longevity improvements have been much stronger than expected, this will be assumed to continue until the liabilities run-off and NN will receive a payment under the hedge. The transaction helped to reduce the solvency capital requirement of NN's Netherlands life business by €35m. The index attachment point for the hedge is close to NN's best estimate, which helps maintain the SCR relief and effective risk transfer over time. The adviser to the transaction was

[112] https://www.lcp.uk.com/media-centre/press-releases/2017/08/buy-in-and-buy-out-volumes-nearly-double/
[113] http://www.artemis.bm/blog/2017/09/14/mmc-pension-offloads-huge-3-4bn-of-longevity-risk-to-reinsurers/
[114] Nick Reeve (2017) BA scheme uses 'captive insurer' in £1.6bn longevity risk hedge, *IPE*, 13 September.
[115] https://www.pensioncorporation.com/media/press-releases/Prudential, PIC Reach $1.2 Billion Longevity Reinsurance Agreement
[116] See para 5.5.5.

Longitude Solutions founding partner Avery Michaelson who had previously been associated with Société Générale's solution for Aegon.[117]

11.50 In April 2015, the UK government introduced 'freedom and choice' pension reforms which gave more flexibility to how individuals could draw down their defined contribution pension pots. In particular, there was no longer a requirement to purchase an annuity.[118] This immediately led to a fall in annuity sales by up to 75%. The situation was not helped by the fall in gilt yields (which led to a corresponding fall in annuity rates) arising from the government's quantitative easing programme introduced after the GFC. In August 2017, a 65-year old with a £100,000 pension pot, could get a level income for life of £4,894: two years before, the amount would have been £5292.[119] By 2017, the following insurers had pulled out of the open market for annuities: Aegon, LV=, Partnership (before it merged with Just Retirement to form Just), Prudential, Standard Life, Friends Life (merged with Aviva), Reliance Mutual, B&CE, and Retirement Advantage. This leaves just six providers left in what was once the world's largest annuity market: Aviva (offering standard and enhanced annuities), Canada Life (standard and enhanced), Hodge Lifetime (standard only), Just (enhanced only), Legal & General (standard and enhanced) and Scottish Widows (standard only).[120]

11.51 In order to reduce the costs of de-risking, pension plans are encouraged to perform some liability reduction exercises, the key ones being:[121]

- Enhanced transfer values (ETVs) – allow deferred members to transfer an uplifted value of their benefits to an alternative arrangement. In August 2017, a 64-year old entitled to an index-linked pension starting at £10,000 from age 65 would be offered a transfer value of £237,000, according to the Xafinity Tranfer Value Index.[122]
- Flexible retirement options (FROs) – allow deferred members aged 55 and over to retire early, or to take a transfer value and secure benefits in a different format from their plan benefits, or to use funds for drawdown purposes
- Pension increase exchanges (PIEs) – allow pensioners to exchange non-statutory increases for a higher immediate pension with lower or even zero future increases (e.g., a £10,000 annual pension with RPI uplifting is replaced by a £12,000 annual pension with no further increases)
- Trivial commutations (TCs) – allow members with low value benefits to cash these in.

The most common exercises currently in the UK are PIEs and TCs – and these can be conducted either before or at the same time as a bulk purchase annuity broking exercise.

11.52 Innovation is a continuing feature of this market. Some examples include (see, e.g., Legal & General and Engaged Investor, 2016):

- Buy-ins and buy-outs with deferred premium payments – to spread costs

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[117] http://www.artemis.bm/blog/2017/12/01/nn-life-gets-index-based-longevity-hedge-from-hannover-re/

[118] https://www.pensionsadvisoryservice.org.uk/about-pensions/pension-reform/freedom-and-choice

[119] Josephine Cumbo, Pensioners hit as annuity rates drop 10% in two years, *Financial Times*, 1 September.

[120] Source: Hargreaves Lansdown, August 2017.

[121] *Professional Pensions* (2016) Risk Reduction and the Extent of Trust in Pension Scheme Advisors and Providers, June, p.26.

[122] Hannah Godfrey (2017) DB transfer values back on the rise in August, *Professional Adviser*, 7 September.

- Phased de-risking using a sequence of partial buy-ins with an 'umbrella' structure to avoid more than one set of contract negotiations – to spread costs
- Accelerated buy-ins – the insurer provides a loan to the plan equal to the deficit (sometimes called a winding up lump sum (WULS)), so that a partial buy-in can take place immediately, with this converting to a full buy-in when the loan has been repaid, with the option of a full buy-out at a later date
- Forward start buy-ins – a standard buy-in with the start date delayed to reflect the level of funding available, with additional options, such as paying deferred members as and when they retire if this is prior to the start date, or the ability to bring forward the start date for an additional fee
- Automated bulk scheme transfers – to reduce risks (introduced in November 2017 by Scottish Widows and Standard Life)[123]
- Top-slice buy-ins – to target the highest value liabilities
- Named-life longevity swap – if the named member lives longer than expected, the insurer pays out the difference (examples being the £400m Bentley plan or an unnamed plan with 90 named pensioners valued at £50m)
- Tranching by age – to reduce costs; according to consultant Punter Southall, a buy-in for pensioners up to age 70 will make a subsequent buy-out within the following 10 years cheaper than a buy-in for the over 70s[124]
- Longevity swaps for small pension plans with liabilities of £50-100m – previously only available for medium (£100-500m) and large plans (above £500m)
- Novation – the ability to transfer a longevity hedge from one provider to another, thereby introducing some liquidity into what had previously been a completely illiquid market. An example would be the reinsurance of a small bulk annuity transaction. Contract simplicity is a desirable feature of such arrangements
- Longevity swap to buy-in conversions – as pioneered by Phoenix Life in December 2016. Solvency II incentivizes buy-in providers to hold longevity insurance, otherwise they pay an additional risk margin. This encourages buy-in providers to seek out schemes which already have a longevity hedge and encourage them to do a buy-in. Another driver is longevity swap providers that are not currently active in the market – such as J.P. Morgan and Credit Suisse – but are still responsible for running off their existing swaps. They might have an incentive to encourage the associated pension plan to novate the swap to a buy-in provider and hence extinguish their liability.[125]
- Insuring away the extreme tail of liabilities in a closed plan after a specified term, such as 5 or 10 years – to reduce costs
- Increasing optionality in contracts to improve flexibility – for example, the option to switch the indexation measure for pensions in payment from the Retail Price Index to the Consumer Price Index if government legislation changes; or the option to secure discretionary benefits, such as actual inflation above a 5% cap; or surrender options; or the option for a contract to be novated to another insurer if a plan wants to buy-in or buy-out benefits with a different insurer in the future.

[123] Michael Klimes (2017) How the first automated bulk scheme transfers happened, *Professional Pensions*, 10 November.
[124] James Phillips (2017) DB schemes insuring wrong tranche of members in buy-ins, *Professional Pensions*, 14 August.
[125] Stephanie Baxter (2017) Converting longevity swaps into bulk annuities: The next de-risking innovation?, *Professional Pensions*, 13 April.

- Combining liability management solutions (such as interest rate and inflation swaps) and bulk annuities in a buy-out – so instead of completing liability management before considering a buy-out, plans do this in a single exercise
- 'Buy-out aware' investment portfolios – used to reduce buy-out price volatility and close the funding shortfall, with the buy-out price locked to the value of the buy-out aware funds once a target shortfall has been reached and whilst the contract documentation for a buy-out is being completed.
- Improved arrangements for handling data errors that arise after a deal has been executed – to reduce pre-deal negotiation requirements and post-deal transaction uncertainty. Common data errors include member gender, date of birth, and benefit amounts for both member and partner. A simplified data error process could deal with these issues in the following way: locking down benefits, removing the need for re-pricing; mechanistically adjusting demographic errors; and using due diligence to check for systematic errors with the data.[126]
- Arrangements to handle deferred members – to improve insurer appetite to assume the additional risk and cost involved. Deferred lives made up almost half the membership of UK defined benefit schemes in the UK. They are much more expensive to hedge for a number of reasons. First, there are problems with their existence and identification. Second, they enjoy a large number of options which need to be priced, e.g., tax-free cash at retirement, trivial commutation, early/late retirement, exchanging partner pension, and pension increase exchanges. Third, their longevity risk is greater, because the longevity improvement assumption used for pricing has greater reliance on the assumed long-run trend and because the much smaller number of deaths experienced provides little guidance in adjusting the mortality projection model used. Fourth, as a direct consequence of the previous points, more capital is needed and this, in turn, increases the demand for reinsurance. These issues can be at least partially mitigated as follows: a robust existence checking procedure is needed involving electronic tracing, assuming a fixed percentage of the pension is exchanged for tax-free cash, setting the assumed retirement date to the scheme's normal retirement date, assuming no pension is exchanged for additional partner pension, restricting the age profile to older deferred members, and restricting the proportion of deferred members in the transaction.[127]

11.53 These are all innovations in the space linking pension plans and insurance companies designed to ease the transfer of pension liabilities (or at least the longevity risk in them) from pension plans to insurance companies. But there is now an increasing sign of capacity constraints within insurance companies. As one consultant said: 'Given the market has historically completed only 150-200 deals in any one year, there is a real risk of capacity constraints in the market, not just from an insurer capital perspective, but also from a resource and expertise perspective'.[128]

11.54 In April 2017, the International Monetary Fund (IMF) released a new edition of its *Global Financial Stability Report*. Chapter 2 ('Low Growth, Low Interest Rates, And Financial

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[126] Andrew Murphy (2017) Developments in longevity swaps, Pacific Life Re, 23 November, IFoA Life Conference. Provided due diligence has been carried out at the outset, subsequent data errors tend to be unbiased in terms of their impact and so average out close to zero.
[127] Andrew Murphy (2017) Developments in longevity swaps, Pacific Life Re, 23 November, IFoA Life Conference.
[128] Martyn Phillips, Mercer (quoted in *Professional Pensions* (2016) Risk Reduction and the Extent of Trust in Pension Scheme Advisors and Providers, June, p.28).

Intermediation') suggests that DB pension funds across the globe might have to cut benefits 'significantly' in the long term because of ultra-low interest rates. Attempts to increase returns by changing asset allocations 'appears feasible only by taking potentially unacceptable levels of risk'. In the face of such low rates, the IMF argues that 'life insurers and pension funds would face a long-lasting transitional challenge to profitability and solvency, which is likely to require additional capital' or would require a 'very high' level of volatility risk to meet their funding goals. However, a combination of risk aversion and regulatory constraints was likely to deter the vast majority from taking this second path. The IMF instead believes that the current situation might work to the benefit of insurers backing buy-ins and buy-outs. With investors increasingly monitoring the size of DB liabilities and the effects on company share prices, profits, and dividends, the IMF said offloading these liabilities to insurers 'is an attractive option' and 'may represent a market-efficient arrangement' and that 'regulation could play an important role in this area by facilitating such transactions'.

12. A Look Into The Future: Potential Longevity Risk Transfer Solutions

12.1 Overview

A number of potential solutions were suggested in the 2006 *Living with Mortality* paper:

- Longevity bond types (e.g., zero-coupon longevity bonds, deferred longevity bonds, principal-at-risk longevity bonds and longevity spread bonds)
- Mortality, longevity and annuity futures
- Mortality options, longevity caplets and floorlets
- Mortality swaptions

These were direct translations from already exiting capital market instruments, but so far none of these, apart from a single longevity spread bond (i.e., Kortis), have been introduced in the longevity risk transfer market. In this section, we look at two potential new solutions that might have a greater chance of being introduced in the near term.

12.2 Potential solution: Longevity-linked securities

12.2.1 A perceived problem with the EIB/BNP Paribas longevity bond was that the reference index might not be sufficiently highly correlated with a hedger's own mortality experience (as a result of population basis risk). An alternative instrument – denoted a longevity-linked security (LLS)[129] – deals, at least partly, with this problem. The concept was inspired by the design of mortgage-backed securities.

12.2.2 The LLS is built around a special purpose vehicle. Individual hedgers on one side of the contract (for example, a pension plan or an annuity provider) arrange longevity swaps with the SPV using their own mortality experience at rates that are negotiated with the SPV manager. The swapped cashflows are then aggregated and passed on to the market. Bondholders gain if mortality is heavier than anticipated.

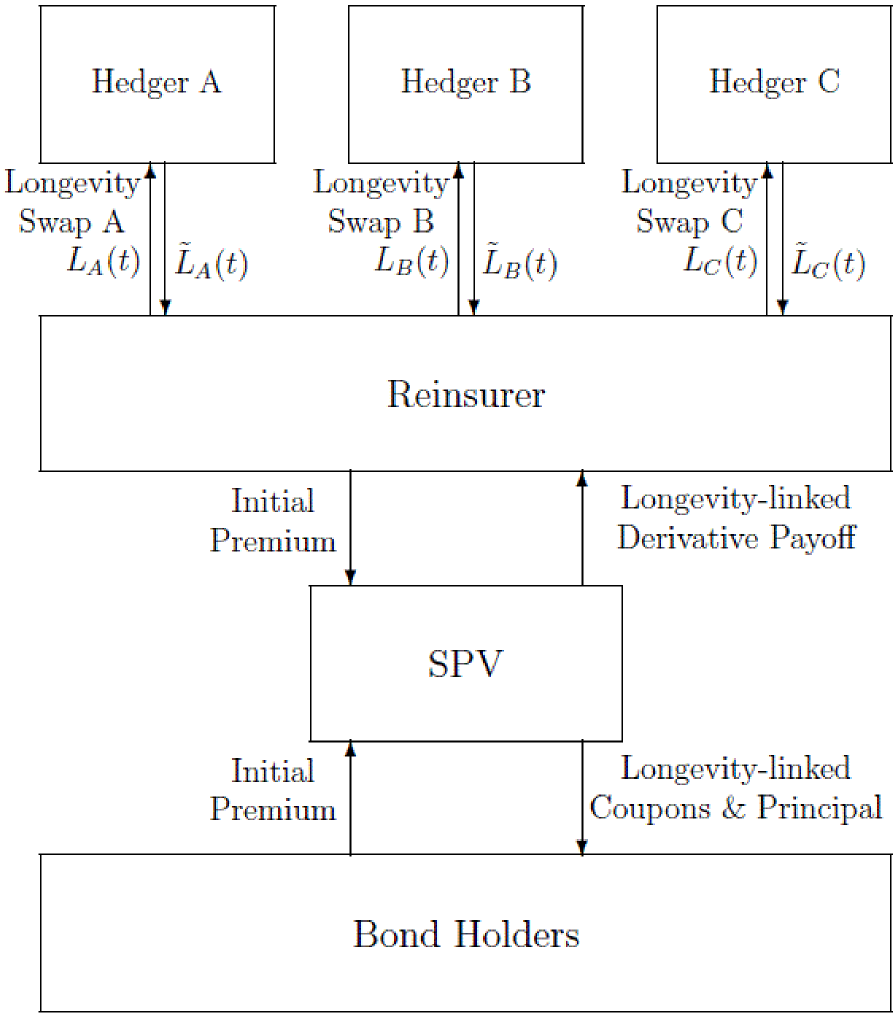
12.2.3 It might be felt that the aggregate cashflows themselves lack transparency[130] in which case the SPV might link cashflows to an accepted reference index. The difference between this and the aggregated swap cashflows is a basis risk that is borne by the SPV manager.

[129] These were first discussed in Cairns *et al.* (2008).

[130] Although this did not seem to be a problem with mortgage-backed securities until the emergence of the GFC in 2007.

12.2.4 This type of arrangement is illustrated in Figure 17 where the intermediary in this case is a reinsurer which transacts customized longevity swaps with a set of hedgers. In this example, there are three hedgers, A, B, and C (but there could, of course, be many more). Hedger A wishes to swap the risky longevity-linked cashflows $L_A(t)$ for a series of pre-determined cashflows. The agreement with the SPV manager is to swap floating $L_A(t)$ for fixed $\bar{L}_A(t)$ for t_= 1, . . . ,T, with the fixed leg set at a level that results in the swap initially having zero value at time 0. Similarly, hedger B swaps floating $L_B(t)$ for fixed $\bar{L}_B(t)$, and hedger C floating $L_C(t)$ for fixed $\bar{L}_C(t)$. The SPV itself invests in AAA-rated, fixed-interest securities of appropriate duration or uses floating rate notes plus an interest-rate swap.

Figure 17: Cash Flows under a Longevity-Linked Security (LLS).



12.2.5 The LLS bond holders pay an initial premium that is used to buy the fixed-interest securities and to pay an initial commission to the SPV manager. The bond holders in return receive coupons and, possibly, a final repayment of principal that is linked to a reference index,

$X(t)$, that matches[131] as closely as possible the combined cashflows, rather than to $L_A(t)$, $L_B(t)$ or $L_C(t)$. Any differences accrue to or are paid by the SPV manager. The bond holders will not normally be hedgers themselves, so they will expect a fair premium over market fixed-interest rates in return for assuming the longevity risk.

12.2.6 Finally, the LLS might take the form of a catastrophe (or cat) bond (similar to the Kortis bond). In this case, the repayment of principal would be determined by the value of an index-based underlying, with appropriate attachment and exhaustion points.

12.2.7 To be more concrete, the underlying index $X(t)$ that the LLS makes reference to is derived from, e.g., national population mortality rates, and is constructed in a way to achieve the optimal balance between hedge effectiveness for the reinsurer within the cat bond structure, and the risk-return profile to investors. For a cat bond with attachment and exhaustion points AP and EP, the payoff at maturity will be the full bond nominal, N, if $X(T) < AP$, $N\big(1-(X(T)-AP)/(EP-AP)\big)$ if $AP \leq X(T) < EP$, and 0 if $EP \leq X(T)$.

12.2.8 The hedge is most likely to be effective if the reinsurer takes on a balanced and well diversified group of transactions with the primary hedgers (A, B and C above). For example, if the primary reinsurance transactions are wholly with blue collar pension plans, then an index-based LLS will be much less effective for the reinsurer. A low level of population basis risk turns out not to require exact matching of the national population (e.g., the aggregation of A, B and C). For example, Cairns et al. (2017a) demonstrate that an aggregated portfolio that covers 80% of the population but is also heavily skewed in value terms towards more wealthier and healthier people can have a correlation with the national population that is well above 95%.

12.2.9 The marketing of LLS to ILS investors has great potential, following the introduction of comprehensive UK regulations for ILS in 2017, particularly if it takes the cat bond structure familiar to such investors, according to consultants Hymans Robertson. This is because longevity risk is becoming better understood and its volatility and correlation with other asset classes is low. Hymans Robertson argues that 'Bulk annuity insurers could use [ILS] to provide additional capital to finance large deals (particularly where reinsurance is expensive or difficult to obtain) or to optimise their capital positions by rebalancing the risks on their balance sheets'. With the ILS investor base broadening all the time and an increasing amount of capital flowing into the market from other sophisticated investor sources, there is a growing pool of capital for which longevity or bulk-annuity linked risks might be attractive.[132]

12.3 Potential solution: Reinsurance sidecars

12.3.1 Another potential solution is the reinsurance sidecar – which is a way to share risks with new investors when the latter are concerned about the ceding reinsurer having an informational advantage.

12.3.2 Formally, a reinsurance sidecar is a financial structure established to allow external investors to take on the risk and benefit from the return of specific books of insurance or

[131] The match might be expressed in cashflow terms or in value terms. In the latter case, the *value* of $X(t)$, is intended to hedge the *value* of the liability at a specified maturity.
[132] Artemis (2017) ILS has potential in UK longevity and backing annuity deals: Hymans Robertson; www.artemis.bm/BLOG/2017/08/21/ILS-HAS-POTENTIAL-IN-UK-LONGEVITY-BACKING-ANNUITY-DEALS-HYMANS-ROBERTSON/

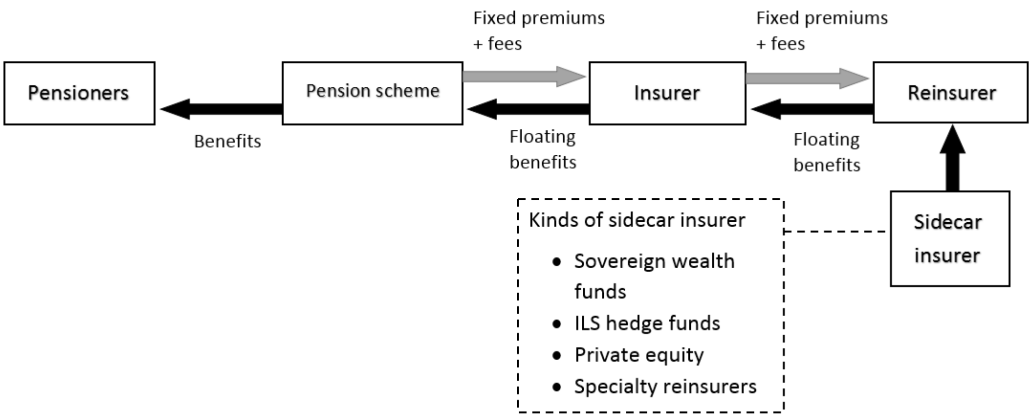
reinsurance business. It is typically set up by existing (re)insurers that are looking to either partner with another source of capital or set up an entity to enable them to accept capital from third-party investors (Kessler *et al.*, 2016).

12.3.3 It is established as a SPV, with a maturity of 2-3 years. It is capitalized by specialist insurance funds, usually by preference shares, though sometimes in the form of debt instruments. It reinsures a defined pre-agreed book of business or categories of risk. Liability is limited to assets of the SPV and the vehicle is unrated.

12.3.4 The benefit to insurers is that sidecars can provide protection against exposure to peak longevity risks[133], help with capital management by providing additional capacity without the need for permanent capital, and can provide an additional source of income by leveraging underwriting expertise. The benefit to investors is that they enjoy targeted non-correlated returns relating to specific short-horizon risks and have an agreed procedure for exiting; investors can also take advantage of temporary price hikes, but without facing legacy issues that could affect an investment in a typical insurer.

12.3.5 Figure 18 shows a typical sidecar structure.

Figure 18: Typical Sidecar Structure



Source: Prudential Retirement

12.3.6 There are a number of challenges to the use of sidecars in the longevity risk transfer market. There is the tension between the long-term nature of longevity risk and investor preference for a short-term investment horizon. There are also regulatory requirements on cedants, affecting their ability to generate a return. These include: the posting of prudent collateral, the underlying assets in the SPV must generate matching cash flows, the risk transfer must be genuine, and the custodian/trustee must be financially strong. There is also a risk to cedants of losing capital relief if regulatory requirements are not met or they change.

12.4 Why could these potential solutions be successful now?

The principal reason why these solutions might be more successful now in a way that they were not a decade ago is the capacity constraint in the (re)insurance industry – it does not have the capital to take on unlimited longevity risk. The *only* long-term solution to this capacity

[133] That is, specific individual cashflows that give rise to the greatest uncertainty in value terms

constraint is to bring in new investors from the capital markets (i.e., to transfer the risk to the capital markets). These investors will include hedge funds, private equity investors, ILS investors, sovereign wealth funds, endowments, family offices and other investors seeking asset classes that have low correlation with existing financial assets. However, two issues need to be resolved. First, the hedger needs assurance that the solution sold to these investors provides an effective hedge. Second, these investors need some assurance that they are not going to be sold a 'lemon'.[134] There have been many attempts over the last decade to provide both types of assurance – without any real success. This time it might be – and certainly needs to be – different.

13. Conclusions

13.1 As Michaelson and Mulholland (2015, p.29-30) point out:

> *the longevity risk inherent in the world's aggregate retirement obligations is far in excess of the amount of risk capital the global insurance industry could realistically bring to bear against this risk.*[135] *Seen in this light, it becomes painfully obvious that vast sums of additional risk capital must be dedicated to adequately managing longevity risk. It is similarly evident that the only source capable of providing such quantities of capital, and thus assuming a meaningful amount of the world's longevity risk, are the global capital markets…. The mission is clear – longevity risk must be successfully turned into an asset class capable of attracting these vast pools of capital, or else the world's retirement systems will struggle to significantly reduce their longevity exposures in an efficient manner. However, developing capital markets solutions that are readily acceptable by a wide spectrum of institutional investors – given the complexity and uncertainty in modelling this long-term risk – requires innovative solutions from dedicated and experienced financial institutions*.

There are four major challenges.

13.2 First, the most successful solutions to date for hedging longevity risk have been via the longevity swap, but swaps and other derivatives are not the type of investment preferred by these long-term investors. Rather, they are more familiar with, and hence prefer, bonds. While short-term mortality bonds have been a success, long-term longevity bonds have not been similarly successful so far. So important work needs to be done in making the design of longevity bonds more attractive to both issuers and holders. However, the Swiss Re strategy of gradual iteration from a successful innovation – as exemplified in the Kortis longevity spread bond which was a modest adaptation of the Vita mortality bond in terms of design and maturity – appears to show a way forward. The two key prizes, if successful, are a much bigger investor base and much greater market liquidity.

13.3 Second, there needs to be a common agreement between market participants on which mortality model to use for the design and pricing of longevity-linked solutions. One of the main reasons why Aegon's deal with Société Générale went ahead in 2013 was that all parties agreed

[134] Originally a 'lemon' was a defective second-hand car offered for sale on an 'as good as new' basis. It now refers to any product where the seller has more information about its true worth than any potential buyer. In other words, the seller has an informational advantage and needs to find a way of demonstrating the true value to the potential buyer in order to secure a sale (see Akerlof, 1970).

[135] Total global reinsurer capital was just $595bn at 31 December 2016 (Aon Benfield, *Reinsurance Market Outlook April 2017*).

to use the same mortality model. Even if a mortality model produces the wrong forecasts – which it is bound to do – as long as those forecasts are not systematically biased, then it becomes a potential candidate for use in this market.

13.4 Third, a number of operational issues need to be dealt with. These include basis risk, credit risk, collateral and liquidity. Not only will this require market participants to work out the optimal trade-offs between basis risk and liquidity and between credit risk and collateral, it will also require the regulator to be willing to grant to maximum possible regulatory capital relief for index-based hedge solutions compatible with current solvency capital requirements.

13.5 Fourth, the regulatory responses to the Global Financial Crisis have had some effect in slowing down the establishment of longevity-linked capital market securities. Regulations restricting the risk-taking activities of investment banks and new bank capital rules (Basel III) are limiting the role that banks can play in the development of this market. It has become much less attractive for banks to warehouse risk while matching longevity hedgers and longevity investors. Furthermore, it has even become much less attractive for them to intermediate, standing in the middle between hedgers and investors, because the long-dated, illiquid credit exposure associated with longevity transactions now carries increased capital requirements.[136]

13.6 These four challenges will need to be addressed in the next stage of the development of this market. But innovation has been an important feature of the longevity market since 2006 and there is every reason to believe that this will continue as the different players in the industry seek to reduce costs, optimize capital and manage risks.

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[136] In April 2012, a number of investment banks – UBS, Credit Suisse and Nomura – pulled out of the Life Market as a result of the additional capital requirements under Basel III. But new insurers and reinsurers entered: Munich Re, SCOR and PICA. The election of Donald Trump as US President and his plan to reduce reduce burdensome regulations, such as the Dodd-Frank Act, might eventually help to assist the development of this market.

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APPENDIX

Table A1 lists UK pension buy-ins over £100m between 2007-2016, while Table A2 lists the publicly announced longevity swaps that have been executed between 2007 and 2016 in the UK.

11. TABLE A1: UK PENSION BUY-INS OVER £100M, 2007-2016

Hedger Name	Size (£m)	Sector	Insurer	Date
Aggregate Industries	305	Mining	Pension Insurance Corporation	Feb 10
Aggregate Industries	135	Mining	Just Retirement Partnership	Jul 16
Aon	150	Financial Services	MetLife (now Rothesay Life)	Jun 09
Aon	105	Financial Services	Pension Insurance Corporation	Mar 12
Aon	210	Financial Services	Pension Insurance Corporation	Oct 14
Aon	890	Financial services	Pension Insurance Corporation	Mar 16
BBA Aviation	270	Aviation	Legal & General	Apr 08
Cable & Wireless	1,050	Communications	Prudential	Sep 08
Cadbury	500	Food Producer	Pension Insurance Corporation	Dec 09
CDC	370	Public	Rothesay Life	Nov 09
Civil Aviation Authority	1,600	Public	Rothesay Life	Jul 15
Cobham	280	Aerospace & Defence	Rothesay Life	Jul 13
Cookson	320	Engineering	Pension Insurance Corporation	Jul 12
Dairy Crest	150	Food Producer	Legal & General	Dec 08
Dairy Crest	150	Food Producer	Legal & General	Jun 09
Friends Provident	360	Financial Services	Aviva	Apr 08
GKN	125	Engineering	Rothesay Life	Jan 14
GKN	190	Engineering	Pension Insurance Corporation	Nov 16
GlaxoSmithKline	900	Pharmaceutical	Prudential	Nov 10

Home Retail Group	280	Retail	Prudential	Jun 11
Hunting	110	Energy	Paternoster (now Rothesay Life)	Jan 07
ICI	3,000	Chemicals	Legal & General	Mar 14
ICI	600	Chemicals	Prudential	Mar 14
ICI	300	Chemicals	Prudential	Nov 14
ICI	500	Chemicals	Legal & General	Mar 15
ICI	500	Chemicals	Prudential	Jun 15
ICI	500	Chemicals	Legal & General	Jun 15
ICI	330	Chemicals	Legal & General	Mar 16
ICI	630	Chemicals	Scottish Widows	Jun 16
ICI	750	Chemicals	Legal & General	Jul 16
ICI	590	Chemicals	Scottish Widows	Sep 16
ICI	380	Chemicals	Legal & General	Sep 16
ICI Specialty Chemicals	220	Chemicals	Prudential	Aug 15
ICI Specialty Chemicals	140	Chemicals	Pension Insurance Corporation	Nov 16
Interserve	300	Construction	Aviva	Jul 14
JLT	120	Financial Services	Prudential	Sep 13
Kingfisher	230	Retail	Legal & General	Dec 15
London Stock Exchange	160	Financial Services	Pension Insurance Corporation	May 11
Meat & Livestock Commission	150	Food Producer	Aviva	Jun 11
MNOPF	500	Shipping	Lucida (now Legal & General)	Sep 09
MNOPF	100	Various	Lucida (now Legal & General)	May 10
Morgan Crucible	160	Engineering	Lucida (now Legal & General)	Mar 08
Next	125	Retail	Aviva	Aug 10
Northern Bank	680	Financial Services	Prudential	Apr 15
Ofcom	150	Public	Legal & General	Jul 08

P&O	800	UK Ports Business	Paternoster (now Rothesay Life)	Dec 07
Pensions Trust	225	Charities	Paternoster (now Rothesay Life)	Jul 08
Philips	480	Technology	Rothesay Life	Aug 13
Philips	300	Technology	Prudential	Jun 14
Philips	310	Technology	Prudential	Sep 14
Pilkington	230	Manufacturing	Pension Insurance Corporation	Aug 16
Smith & Nephew	190	Medical	Rothesay Life	Jan 13
Smiths Group	250	Engineering	Legal & General	Mar 08
Smiths Group	250	Engineering	Paternoster (now Rothesay Life)	Sep 08
Smiths Group	150	Engineering	Rothesay Life	Sep 11
Smiths Group	170	Engineering	Pension Insurance Corporation	Sep 13
Smiths Group	250	Engineering	Pension Insurance Corporation	Oct 16
Tate & Lyle	350	Food Producer	Legal & General	Dec 12
Taylor Wimpey	205	Housebuilding	Partnership	Dec 14
The Church of England	100	Charities	Prudential	Feb 14
Total	1,600	Oil and Gas	Pension Insurance Corporation	Jun 14
Undisclosed	145	Undisclosed	Legal & General	Jan 09
Undisclosed	220	Retail	Legal & General	Mar 09
Undisclosed	100	Manufacturing	MetLife (now Rothesay Life)	Jan 10
Undisclosed	100	Retail	Aviva	Mar 10
Undisclosed	185	Banking	Aviva	Dec 10
Undisclosed	120	Undisclosed	Legal & General	May 11
Undisclosed	145	Property	MetLife (now Rothesay Life)	Nov 11
Undisclosed	250	Media	Aviva	Dec 11

Undisclosed	110	Undisclosed	Aviva	Dec 11
Undisclosed	250	Undisclosed	Legal & General	Aug 12
Undisclosed	140	Undisclosed	Prudential	Aug 12
Undisclosed	120	Undisclosed	Pension Insurance Corporation	Nov 12
Undisclosed	100	Undisclosed	Pension Insurance Corporation	Dec 12
Undisclosed	100	Undisclosed	Pension Insurance Corporation	Apr 13
Undisclosed	200	Undisclosed	Pension Insurance Corporation	Nov 14
Undisclosed	300	Unknown	Aviva	Jun 15
Undisclosed	120	Undisclosed	Just Retirement	Oct 15
Undisclosed	200	Undisclosed	Scottish Widows	Apr 16
Undisclosed	130	Undisclosed	Just Retirement Partnership	Jul 16
Undisclosed	150	Undisclosed	Pension Insurance Corporation	Sep 16
Undisclosed	100	Undisclosed	Pension Insurance Corporation	Sep 16
Undisclosed	245	Unknown	Pension Insurance Corporation	Nov 16
Undisclosed	105	Undisclosed	Pension Insurance Corporation	Nov 16
Undisclosed*	120	Undisclosed	Rothesay Life	Jun 14
Unilever	130	Consumer goods	Legal & General	Sep 14
Weir Group	240	Engineering	Legal & General	Dec 07
West Ferry Printers	130	Printing	Aviva	Sep 08
West Midlands Integrated Transport Authority	270	Transport	Prudential	Apr 12
Western United	115	Mining	Rothesay Life	Nov 12
Western United	110	Food Producer	Rothesay Life	Mar 14
Wiggins Teape	400	Manufacturing	Scottish Widows	Nov 15

Source: LCP (Professional Pensions, 26 January 2017)
Notes: Information collected from insurance company data and publicly announced transactions in H2 2016.
Notes: * This deal was completed during Q3 2014

12. TABLE A2: UK LONGEVITY SWAPS, 2007-2016						
Date	Hedger	Type	Size (£m)	Term (yrs)	Format	Receiver or Intermediary
April 2007	Friends' Provident	Ins	1700	Run-off	Reinsurance contract	Swiss Re
Feb 2008	Lucida	Ins	N/A	10	Index-based hedge; exposure placed with capital market investors	J. P. Morgan
Sep 2008	Canada Life	Ins	500	40	Exposure placed with capital market investors	J. P. Morgan
Feb 2009	Abbey Life	Ins	1500	Run-off	Reinsurance contract	Deutsche Bank
Mar 2009	Aviva	Ins	475	10	Exposure placed with capital market investors & Partner RE	RBS
May 2009	Babcock	PF	500-750	50	Reinsurance contract with Pac Life Re	Credit Suisse
July 2009	RSA	Ins	1900	Run-off	Reinsurance contract with Rothesay Life; combined with inflation & interest rate swaps	Goldman Sachs/Rothesay
Dec 2009	Berkshire Council	PF	1000	Run-off	Reinsurance contract	Swiss Re
Feb 2010	BMW	PF	3000	Run-off	Reinsurance contract	Deutsche Bank, Paternoster
July 2010	British Airways	PF	1300	NA	Synthetic buy-in (longevity swap + asset swap)	Goldman Sachs/Rothesay
Feb 2011	Pall (UK)	PF	70	10	Index-based hedge;	J.P.Morgan

12. TABLE A2: UK LONGEVITY SWAPS, 2007-2016						
Date	Hedger	Type	Size (£m)	Term (yrs)	Format	Receiver or Intermediary
					exposure placed with capital market investors	
Aug 2011	ITV	PF	1700	NA	Reinsurance contract	Credit Suisse
Nov 2011	Rolls Royce	PF	3000	NA	Pensioner bespoke longevity swap	Deutsche Bank
Dec 2011	British Airways	PF	1300	NA	Pensioner bespoke longevity swap	Goldman Sachs/Rothesay
Dec 2011	Pilkington	PF	1000	NA	Pensioner bespoke longevity swap	Legal & General
April 2012	Berkshire Council	PF	100	Run-off	Insurance contract	Swiss Re
May 2012	Akzo Nobel	PF	1400	NA	Insurance contract	Swiss Re
July 2012	Pension Insurance Corp	Ins	300	NA	Insurance contract	Munich Re
Dec 2012	LV=	Ins	800	NA	Insurance contract	Swiss Re
Dec 2012	Pension Insurance Corp	Ins	400	NA	Insurance contract	Munich Re
Feb 2011	Pall (UK)	PF	70	10	Index-based hedge; exposure placed with capital market investors	J.P.Morgan
Aug 2011	ITV	PF	1700	NA	Reinsurance contract	Credit Suisse
Nov 2011	Rolls Royce	PF	3000	NA	Pensioner bespoke longevity swap	Deutsche Bank
Dec 2011	British Airways	PF	1300	NA	Pensioner bespoke longevity swap	Goldman Sachs/Rothesay
Dec 2011	Pilkington	PF	1000	NA	Pensioner bespoke	Legal & General

12. TABLE A2: UK LONGEVITY SWAPS, 2007-2016						
Date	Hedger	Type	Size (£m)	Term (yrs)	Format	Receiver or Intermediary
					longevity swap	
April 2012	Berkshire Council	PF	100	Run-off	Insurance contract	Swiss Re
May 2012	Akzo Nobel	PF	1400	NA	Insurance contract	Swiss Re
July 2012	Pension Insurance Corp	Ins	300	NA	Insurance contract	Munich Re
March 2014	Aviva Staff Pension Scheme	PF	5000	NA	Insurance contract	Munich Re, Scor and Swiss Re
May 2014	Royal London	Ins	1000	NA	Insurance contract	RGA International
July 2014	BT Pension Scheme	PF	16000	NA	Insurance contract	Prudential Insurance Co of America
August 2014	Rothesay Life	Ins	1000	NA	Insurance contract	Prudential Insurance Co of America
August 2014	Phoenix Group Pension Scheme	PF	900	NA	Insurance contract	Phoenix Life
October 2014	Legal & General	Ins	1350	NA	Insurance contract	Prudential Retirement Insurance and Annuity Co of America
Dec 2014	Rothesay Life	Ins	1000	NA	Insurance contract	Pacific Life Re
January 2015	Rothesay Life	Ins	300	NA	Insurance contract	Prudential Insurance Co of America
January 2015	Merchant Navy Officers' Pension Fund	PF	1500	NA	Insurance contract	Pacific Life Re
February 2015	Scottish Power	PF	2000	NA	Insurance contract	Abbey Life
April 2015 and June 2015	Pension Insurance Corp	Ins	>1600	NA	Insurance contract	Prudential Insurance Co of America
July 2015	AXA UK Pension Scheme	PF	2800	NA	Insurance contract	RGA International

12. TABLE A2: UK LONGEVITY SWAPS, 2007-2016

Date	Hedger	Type	Size (£m)	Term (yrs)	Format	Receiver or Intermediary
August 2015	Legal & General	Ins	1850	NA	Insurance contract	Prudential Insurance Co of America
September 2015	Scottish & Newcastle	PF	2400	NA	Insurance contract	Friends Life, Swiss Re
November 2015	RAC (2003)	PF	600	NA	Insurance contract	SCOR Se
December 2015	Unnamed	PF	90	NA	Insurance contract	Zurich, Pacific Life Re
April 2016	Legal & General	Ins	NA	NA	Reinsurance contract	Prudential
August 2016	Scottish Power	PF	1000	NA	Reinsurance contract	Abbey Life
August 2016	Pirelli	PF	600	NA	Reinsurance contract	Zurich, Pacific Life Re

Note: Ins – hedger is insurance company; PF – hedger is pension fund, http://www.artemis.bm/library/longevity_swaps_risk_transfers.html